SR

A Collection of Chemical Lecture Experiments

BY

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PREFACE.

There are several very good books about lecture-table demonstrating on the market and the only excuse for this one is the fact that chemistry strides so fast that the books already published are out of date.

It is not the intention to have a complete list of elementary lecture experiments in this book. Those herein contained are new, or are modifications of old ones. For a very complete set of lecture-table demonstrations of the conventional type, teachers should refer to the older books.

The author wishes to thank the many friends whose suggestions have been of great value in preparing this little book for publication. Especially he wishes to thank Mr. William G. Chace, his assistant, for his extremely important aid in verifying nearly every experiment from the directions as they are herein printed.

Corrections and criticism will be welcomed.

H. F. Davison.

Brown University,
Providence, R. I.

NOTE TO THE READER

The work which Professor Davison loved best of all was teaching. He believed it to be among the noblest of callings, and he devoted himself to it with all the power that was his. Realizing that the mind of the student often can be reached and interested even more through the eye than the ear, he developed a skill in lecture table demonstrations rarely surpassed. After the experiences of nearly a quarter of a century, he felt he would like to pass on to his colleagues the methods worked out with so much care. Thus the present volume was planned, and took shape.

The book was almost ready for the press when, upon returning home from a day of pleasant labor, its author was suddenly stricken with a cerebral hemorrhage; and even before his friends and colleagues were aware of the fact, he had passed away.

Mr. Horace B. Pray, for many years student and instructor under Professor Davison, has carefully gone over all the manuscript, but it is presented, nevertheless, essentially unaltered. It is dedicated to the teachers of chemistry, in the sincere hope that some of the best of the writer's work may indeed live after him, in the service of the profession for which he cared so much.

L. A. Bigelow.

July, 1926.

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THE ART OF LECTURE TABLE DEMONSTRATING

Chemistry is a study of matter and it can never be adequately learned from books. Students must see the material that is talked about and must eventually handle it themselves. But beginners have to be shown what chemicals will do and how they are best handled. This is the business of the teacher, who must be something of a demonstrator at the lecture table if he is to be successful in arousing the interest of his pupils. There can be nothing more stupid than a long-winded attempt to tell how sulfuric acid is made, what its properties and its uses are, without showing the actual process of its manufacture and its chemical action by various experiments. One may just as well try to draw word pictures of beautiful paintings expecting that these can satisfy as well as the realities.

The eye is wonderfully quick to perceive what the brain cannot, at the moment, encompass, but the mental impression provoked by the eye will last for years, to be better understood in later days perhaps.

Much teaching of chemistry is for students who do not intend to continue it beyond one year and for these the only chance to become acquainted with much of what chemicals are and do is by watching the teacher as he puts the substances talked about through their paces. It profits a man not much if he *tells* his fellow townsmen he has a fast horse. But it profits a teacher much if he shows his pupils chemicals will do under proper guidance.

There are certain fundamental rules to foll demonstrating. It goes without saying that th periments must work. Nothing is more fatal t cess in this line of work than any considerabl centage of failures. Far better is it to have no d strations than to have "fizzles". It is easy to sa "the experiment worked last night" or that the " icals are old" or what not, but the moment y say any such thing the confidence of the studen lessened. If, as sometimes does happen, som foreseen condition makes havoc with your demo tion, it is best to state what you believe is the tr promise to show the experiment properly at future time, and do it. Confidence that you wer to do what you had promised will again posse students and your position will be thereby strengthened.

I have seen a demonstrator keep his spectato edge" for a long time, trying hard to make thing "work", until both spectators and demo tor were in a cold sweat, and out of this much nothing was born. It would be far better under circumstances to stop than to try hard.

There can be no doubt that men who make demonstrations before a class, must have a n aptitude for handling apparatus and making it results. The demonstrator must have a certain a of manual dexterity, which, while it may be acc to a certain degree by long practice, is gener "knack" which the man had before he thoug performing experiments before a class.

To be a good and original demonstrator requires that one should know how to work with materials. Soldering, glass working, cementing, drilling, cork boring, and all the minor operations of the worker in laboratory materials should be as familiar as eating a meal.

An ability to "set up" apparatus is a prime requisite in a demonstrator. A man who ties up loose joints between glass and rubber tubing with string will never make a first class demonstrator.

The secret of success before a class is in the preparation before the class comes in. It does no harm to the most seasoned veteran to run through his demonstrations before his class appears.

Experiments should be simple and speedy. Complicated apparatus is out of place before a class. The author once saw a complete water-gas plant operated before a group of teachers. Three men attended it, and after about a half-hour succeeded in getting just gas enough to light. Needless to say there is little educational value in that sort of experimentation. Any experiment which takes over five minutes will be of doubtful value. There is nothing more trying to students or teacher than to have to wait a considerable time for something to happen. Interest in the experiment lags and then is just the time that those students who like to make a joke of the course or of the teacher, attempt it. One should see to it that his experiments go quickly to a conclusion. Much of the author's time has been devoted to the speeding up of lecture-table demonstrations and to simplifying the apparatus.

To expedite work at the lecture table, all materials should be weighed by measure. Take an example. Suppose a given experiment requires 10 grams of powdered sulfur. It is not doing the student any good to wait while you weigh this amount out on the balance. What you should do is to find some small beaker or dish which, level full, holds approximately the required 10 grams. This may be marked and put away with the rest of the apparatus for this experiment. Liquids should not be measured in graduates, generally, but a test tube known to hold the required amount when full, is used. Of course occasions arise where, as in titrating before a class, accuracy of measuring must be looked out for, but for the ordinary lecture demonstrations it is far better not to have to resort to graduates. It sometimes pays both in solids and liquids to have the right amounts weighed out or measured out before the class comes in.

Never should one attempt to set up apparatus after the lecture has begun. Have everything in readiness beforehand. Nothing is so disconcerting to students as to have the lecturer fumble around in the cupboards under the lecture table for a ringstand or gauze which should have been ready when he started to lecture.

There is a tendency on the part of lecturers to forget that it is to the class the experiments are being shown, and not to those who are performing them. Experiments should be set out near the front edge of the table, and care should be taken that students who sit off at the sides of the room do not have their vision obstructed by other pieces of apparatus which may be on the bench.

The size of the apparatus which it is best to use has to be left to the judgment of the individual teacher and depends of course, on the size of his lecture room. Some experiments do not admit of performance on a large scale. The author deplores very much the great increase in the size of lecture rooms in recent years, for in only a relatively small lecture room holding two hundred and sixty students he finds it is difficult for the students in the rear of the room to see what is going on in front. In one very large lecture room in a University which he visited, the author was told that many of the students had to bring field glasses in order to see much of anything that was going on at the lecture table. There is a long span of educational history between Mark Hopkins, a log and a student, as the constituents of a college, and such a college that the professor and his students are at telescopic range, physically and probably out of range personally.

Much time in succeeding years can be gained by putting away the apparatus used for a given experiment on a shelf by itself, to remain together until called into use again. This, of course, entails the use of considerable "dead" stock because many pieces of apparatus have to be duplicated on the shelves. A modification of this plan might be used with profit. Such articles as iron ware, bottles, hydrometer jars and precipitating jars which are in common use, may be taken at each lecture from the common stock, but all special pieces like bent tubing, special sizes of jars, special apparatus ready set up should certainly be retained in some special place for future use.

All the apparatus stored should be thoroughly cleaned before storage and glass stoppers should be insured against sticking by insertion of a piece of paper between the stopper and bottle neck. No chemicals that can decompose or deliquesce should be allowed to remain. The author once got into serious trouble by leaving soda lime used as a dryer for ammonia, in the drying column. The next year a cake had formed over the top, and, acting as a plug, nearly caused the bursting of the whole apparatus. A stopper fortunately blew out, indicating that trouble was imminent, but the class was subjected to a gas attack not at all pleasant.

No experiments should ever be shown *simply* because they are spectacular. Students soon become irked by these. Every experiment shown should have a definite purpose to show some chemical truth and that truth should be forcibly brought home. There are plenty of spectacular experiments, to be sure, but their scientific import is to be emphasized rather than their value as entertainment. Even the simplest demonstration can sometimes be used to show a great truth and will become absorbingly interesting to inquisitive students.

In the writer's student days, a very complex demonstration of the chamber process of sulfuric acid manufacture was shown. But the cumbersome apparatus got more attention than the reactions going on. A very simple demonstration to be found elsewhere in this book serves the purpose much better in the opinion of the writer, because the apparatus used has no attraction away from the process, and in five minutes can be shown all that required fifteen or twenty with the more complex apparatus.

One must never be too sure that students grasp the import of a lecture table experiment. After having shown a set of three perfectly lucid experiments to prove that hydrogen gets through small openings faster than air does, the writer gave a test and asked the question, "How can it be shown that hydrogen goes through a small opening faster than air can get through"? The student whose answer follows was present when the demonstrations were made. The answer is here reproduced as nearly as possible like the original. "If you fill a glass bottle with hydrogen and put a piece of curved glass tubing in the mouth of bottle so that it runs from bottle in a curve to outside thus: (Here is a diagram which has been crossed out and substituted by another which looks like an army revolver). Also allow no air to enter bottle—that is thrust the curved tubing through a one-holed rubber bottle cork. Then it will be noticed (Here I am referred by a long scrawled line terminating in an arrow head to the preceding page for a continuation of the discussion) that the hydrogen will go through the small opening which is inside the bottle much faster than air goes through the small opening of the tubing, on the outside of the bottle. Thus hydrogen is better for running mills than oxygen. For example, our factories run by water power." I defy even a professor of chemistry to fathom out what experiments that student saw.

In spite of this horrible example, I believe that most students get the point of a good demonstration and that the impression made by it lasts a lifetime.

It must be perfectly obvious that not every chemical reaction can be shown as a demonstration and the blackboard must be used for these. And it is equally obvious that the blackboard can supplement the demonstration and should be used freely. The most effective demonstrators try to cultivate the art of talking in connected sentences while performing the experiments. Perfection in this is hard to attain, especially when something "hangs fire." Nevertheless one may often cover the awkward situation by a free use of his mother tongue.

It is hard work to get up good demonstrations and unless one is willing to put at least as much time on the average in getting them ready, as he takes to show them, he will probably never be especially convincing to his students.

EXPERIMENT NO. 1

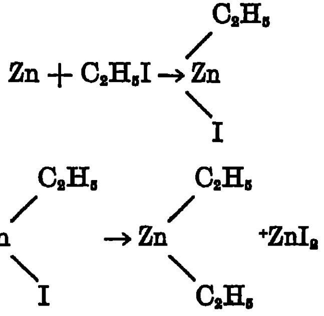
ZINC ETHYL

When discussing combustion it is well to emphasize the fact that some substances have kindling points below the ordinary room temperature. In order that burning shall take place we must have a combustible, a supporter of combustion, and a favorable temperature (kindling point).

Zinc ethyl is, at room temperature, already above its kindling point, but kept sealed up, lacks the necessary oxygen to support its combustion. A tube of it broken into the air gives all three conditions and combustion ensues. A tube may also be thrown high in air and allowed to break on the floor of the lecture room.

It is obvious that this is a dangerous substance to have around and it should be made and stored with great care.

Preparation:



$$Zn + C_2H_5I \rightarrow \overset{C_2H_5}{\underset{I}{Zn}}$$

$$2\overset{C_2H_5}{\underset{I}{Zn}} \rightarrow \overset{C_2H_5}{\underset{C_2H_5}{Zn}} + ZnI_2$$

Take 72 grams of powdered zinc and mix with 8 grams of copper powder and place in a 250 cc. round bottom flask with a two-hole stopper. In one of the holes place a small glass tube with a right angle bend put through the stopper. In the other hole place a longer tube extending nearly to the bottom of the mixture. Through this pass slowly a current of hydrogen. Heat strongly at the same time shaking until a gray mass is formed, but do not allow any fusion. The mass appears to be damp when it has been heated long enough. Allow the flask and contents to cool. The product is called a zinc copper couple.

Be sure that all the apparatus is perfectly dry from this stage on.

When the zinc copper couple has cooled to room temperature connect the flask containing it to a vertically mounted condenser down which 80 grams of ethyl iodide are carefully poured. Heat on a water bath until drops of the ethyl iodide no longer run back into the flask. The necessary heating takes about one hour, and the cessation of the return flow of ethyl iodide (B.P.72°) indicates its change to zinc ethyl iodide as the equations indicate.

Next insert the two-hole stopper and its connecting tube which was used in making the zinc-copper couple into the flask, attaching a condenser in the ordinary oblique position for distilling to the right angled tube.

Attach a side-neck distilling flask by means of a stopper to the end of the condenser, using this flask as a receiver. Pass a very gentle stream of carbon dioxide through the whole apparatus.

Heat the reaction mass with a free flame (with caution) until no more liquid distills over into the receiver. The product will be pure enough for the purpose intended, but could be redistilled if desired.

Next attach the carbon dioxide delivery tube to the side neck of the flask containing the distillate and, clamping the flask in an upright position allow a gentle stream of carbon dioxide to pass through the open mouth of the flask.

Small test tubes (10 cm.) are heated in their middles until soft and drawn out slowly into small capillary tubes which are broken off at such length as will reach the bottom of the flask containing the zinc ethyl. Heat one of these in the flame until the flame becomes tinged with yellow and immediately dip the capillary under the zinc ethyl allowing the bulb to cool in this position. The liquid will rise in the bulb. A little practice will show how long to heat to collect a given amount by the vacuum produced.

Seal off the capillary close to the bulb, in the open air, being sure to keep out of the way of the liquid ejected from the capillary by the heat.

EXPERIMENT NO. 2

THE SENSITIVE FLAME

A flame which is remarkably sensitive to sound waves can be very easily made, and offers much for speculation in regard to its operation. This is a modification of a device described in the "Zeitschrift für den Physikalischen und Chemischen Unterricht" for November 1920, page 229.

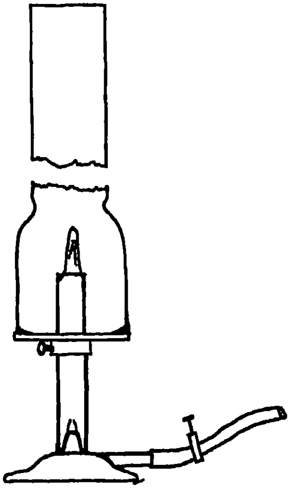


Figure 1

An ordinary Bunsen burner is taken apart and the flattened jet through which the gas issues is cut off and in its place is soldered the tip of an ordinary brass laboratory blow-pipe. The ring which closes the air openings is removed and the holes closed by soldering on brass covers.

A tripod wind shield support commonly used in laboratories is fastened about ½ of the distance down from the top of the burner tube and on this a student-lamp chimney rests. The chimney may be supported by any other convenient means, however. Gas is led to this burner through a rubber tubing on which a screw pinch-clamp is placed. The gas being turned on full, it is possible to light it at the top of the chimney. If now the pinch-clamp is screwed up, the flame will finally be of a conical shape and will burn just below the rim of the burner tube.

By very slightly varying the flow of gas, now, a point will be found, at which the flame will bob down when the letter "A" is pronounced, but will fail to do so when the letter "E" is pronounced.

The other vowels "I", "O", and "U" have the same effect as "A".

EXPERIMENT NO. 3

CARRYING FLAME IN HANDS

There are tricks in all trades.

Place the thumb of the right hand crosswise on the thumb of the left hand. Keeping the fingers naturally curved and close together, place the tips of the fingers of the right hand on the first finger of the left hand and at right angles to it. Slide the fingers of the right hand to close the space between the first finger and thumb of the left hand, and let the tips of the fingers of the left hand press firmly against the side of the right hand. If properly done this will produce a deep cup shaped opening which is practically gas tight. Practice this several times.

Have two good Bunsen burners lighted and about 25 cm. apart. Turn the right hand one down to about a 5 cm. flame, and shut off the air supply of the other, producing a yellow flame of the full size the burner will give.

Place the finger of your right hand directly onto the top of the burner tube, extinguishing the flame. Do this with firmness and without hurry. You will not be burned.

Now cup your hands as indicated and hold them over the extinguished burner, getting a full charge of gas in them. Carry this quickly over to the lighted burner and back to the unlighted one, which, if you have been skillful, will be lighted by the burning charge you have carried in your hands.

EXPERIMENT NO. 4

DUST EXPLOSION

A friction-top cylindrical can, 25 cm. high and about 20 cm. in diameter, has a circular hole cut in the bottom large enough to take the stem of a small glass funnel whose largest diameter is about 8 cm. This is provided with a rubber tube about 1 meter in length, the free end being fitted with a fire polished

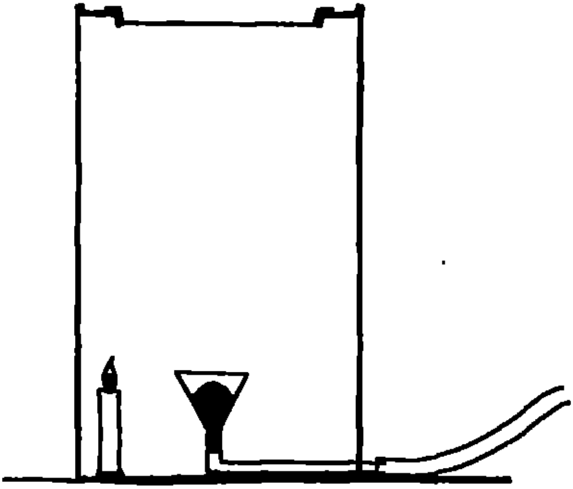


FIGURE 2

glass mouth-piece. The apparatus is set up on a tripod.

To show the explosion, take about 25 cc. of lycopodium powder and pour this into the funnel. When all the dust has settled, place a lighted candle which is not over 4 cm. high, on the bottom of the can, near one side. Put the friction-top firmly into place. Stand away the length of the tube and blow a vigorous and prolonged puff of air through the tube. The explosion should blow the cover 2 meters into the air and the intensely hot flame will go up 1 meter. It is well to have the spectators at a little distance, although with a cover of large area there appears to be no possibility of the can itself bursting. The cans used to hold salted peanuts are of exactly the right dimensions for a successful piece of apparatus.

To obviate using a tripod a lead tube may be soldered in as is indicated in the drawing and a tin funnel connected.

EXPERIMENT NO. 5

AIR PRESSURE

A convincing experiment which shows the pressure of the atmosphere is very easily carried out. A new, one gallon, flatsided varnish can has a layer of water about 1 cm. deep put into it. It is then put on a tripod over a flame, and the water boiled vigorously for about three minutes. A sound cork stopper which has been soaked in melted paraffin, or better a rubber stopper, is put into the opening of the can at the moment the flame is removed. The can is now grasped by the handle with tongs and cold water is poured over it. It becomes a shapeless mass from the crushing effect of the air outside which is not counter-balanced by a corresponding pressure inside, since the air has all been driven out by the steam.

EXPERIMENT NO. 6

OXIDATION OF FERROUS SALTS TO FERRIC SALTS

The easiest way to show this on the lecture table is to take pure ferrous sulfate solution, add it to a solution of ammonium sulfocyanate and to oxidise the ferrous salt while in solution, to the ferric, with concentrated nitric acid.

The ferrous sulfate must be wholly clear of ferric salts and this is accomplished by putting into a ferrous sulfate solution a wad of steel wool. An Erlenmeyer flask serves to hold the solution and the wool and the latter should be of such quantity that every part of the solution has some steel wool in it.

The ferrous sulfate solution should be made up, using 10 grams of crystallised ferrous sulfate to 1 liter of distilled water. One hundred cubic centimeters of this are put into a precipitating jar and 25 cc. of 10 per cent solution of ammonium sulfocyanate are added. No red color should develop at this stage but on the addition of 10 cc. of concentrated nitric acid the oxidation will immediately take place and the red color will develop due to the formation of ferric sulfocyanate.

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EXPERIMENT NO. 7

CARBON MONOXIDE

The simplest and, although simple, sufficient method for showing the combustibility of carbon monoxide is to take an extra large test tube, 20 cm. by 4 cm., and put about 10 grams of sodium formate in the bottom. To this is added 10 cc. of concentrated sulfuric acid.

The dehydrating action proceeds rapidly and carbon monoxide is produced and may be lighted at the mouth of the test tube showing the characteristic blue flame. This experiment should by all means be done in the hood.

EXPERIMENT NO. 8

CLEANSING ACTION OF SOAP

The cleansing action of soap depends upon two qualities which it possesses; that of adsorbing fine particles of solid which may get onto a surface and its power to emulsify oils which can then be washed away in the form of small globules.

The ability to do both of these can be easily demonstrated as lecture experiments.

Two Erlenmeyer flasks of about 500 cc. capacity have put into each a teaspoon of lamp black. 300 cc. of water is added to each flask and both flasks are moderately shaken simultaneously before the class. Lamp black being a non-wetted powder does not scatter through the water but remains as a layer on the surface. If now, to one of these flasks is added a teaspoon of liquid soap, it will be seen that the powder immediately disperses toward the sides of the flask, sticking thereto quite firmly.

If now, the flasks are again moderately shaken simultaneously, it will be seen that the lamp black in the presence of the soap solution, mixes thoroughly with the water and as the water is poured out the lamp black goes with it. Thus it can be seen that rinsing the hands after having thoroughly rubbed them will carry off such dirt particles as are represented by the lamp black.

Oils which may be on surfaces to be cleansed are emulsified by soap and can easily be rinsed away in the form of small globules, whereas, the film of oil is not removed at all by water.

Kerosene and water in equal volumes are mixed by shaking in a tall, narrow cylindrical bottle. On allowing these to come to rest, the globules soon coalesce in a layer at the top whose surface is as small as possible under the circumstances. Likewise the water is occupying such shape as to give itself the least surface, this being the result of its surface tension. Anything put in to lower the surface tension will make it possible for the water to have much larger surface, i.e. its tendency to form a layer will not be so great, and the oil globules once formed can remain a long time in the water.

If, now, to the mixture of oil and water, about 10 cc. of liquid soap are added, on shaking thoroughly, the oil and water will emulsify and if a stream of water is run through a tube to the bottom of the bottle, practically all of the oil will be forced out of the bottle in the form of the emulsion.

Oils which are saponifiable (capable of making a soap), are emulsified simply by adding some substance which gives a basic reaction. Hence it is possible to wash off such oils without soap by using sodium carbonate (sal soda). This may be shown by taking linseed oil which is saponifiable and in a tall, narrow bottle, adding to it in equal volume a 10 per cent solution of sodium carbonate. On shaking, the emulsion will be perfect and lasting.

EXPERIMENT NO. 9

COMMON SOLUBILITY

To show that a solution of common salt saturated with respect to the salt, is not saturated with respect to other salts, take a saturated solution of salt (200 cc.) making sure that it is saturated at the temperature shown by having an excess of salt in it. To this now add 5 grams of copper sulfate broken up into small particles. The color will soon go through the whole solution showing that the copper sulfate still finds room into which to diffuse. An interesting question arises as to why it is that the color is green rather than blue, which is the color of copper sulfate solution if no common salt NaCl is present. See Denham, Inorganic Chemistry, page 504.

EXPERIMENT NO. 10

THE ACTIVITY OF METALS

A good demonstration of the relative activities of the five metals, potassium, sodium, calcium, magnesium, and aluminium, can be shown by placing out on the lecture table five precipitating jars containing equal amounts of water (200 cc.) to which has been added in each jar 10 cc. of concentrated hydrochloric acid. All the water should be at the same temperature (about 10° C).

The pieces of potassium and sodium should be of such size that if in cubical form, they would be about 5 mm. on each side. These are put on the surface of the water, one in each of two of the precipitating jars and into the third calcium chips, in bulk about 1 cc., in the fourth magnesium chips, and in the fifth, granular aluminium in amounts equal to the calcium. Since these will all be put in at about the same time, it can easily be seen which is more active and what are the relative actions of the others by the rate at which hydrogen is evolved and the metal used up.

EXPERIMENT NO. 11

HYDROLYSIS OF ALUMINIUM SULFIDE

Practically complete hydrolysis of salts formed from weak acids and weak bases, is very easily shown with aluminium sulfide. This being a salt of aluminium hydroxide and hydrosulfuric acid both of which are weak) hydrolyzes practically completely to these substances. The hydrogen sulfide being only slightly soluble, passes off and can be made to show its presence on lead acetate paper.

A tall, narrow beaker, capable of holding 500 cc. has 50 cc. of water put in the bottom and two grams of aluminium sulfide added. At once the gaseous hydrogen sulfide will come off and may best be shown by hanging a piece of filter paper wet with lead acetate solution on a glass rod which rests on the edges of the beaker. The hydroxide being insoluble will settle to the bottom of the beaker and the liquid may be decanted from it.

This method is a very useful one to get small amounts of H_2S for lecture table use.

EXPERIMENT NO. 12

FREE ALKALI IN SOAP

A soap such as Pears' Soap exhibits no free alkali. This may be compared with some other soap like common laundry soap to show the difference, very easily.

The two soaps to be compared have shavings taken from the cakes, approximately equal quantities of the two soaps being taken.

These are then brought into solution in 50 cc. of ordinary 95 per cent alcohol to which 100 cc. water have been added. This amount of water in the alcohol is sufficient to show the presence of ions if free sodium hydroxide is present, but shows no ions with the soap containing no free alkali. These facts are made evident by adding a couple of drops of phenolphthalein solution to each, whereupon the laundry soap solution will show pink, but the other will remain colorless. The solutions are best contained in cylindrical graduates or footed test tubes.

EXPERIMENT NO. 13

EXPLOSION OF HYDROGEN-CHLORINE MIXTURE BY LIGHT

NOTE: Do this experiment in the lecture table hood or have a draft blowing across the lecture table and a screen between the experiment and the audience.

This classic experiment would seem to be incapable of change, but in our more modern laboratories in which our gases are provided in tanks it is extremely easy to show the experiment. The older method of filling thin, glass balloons with a mixture obtained by electrolysis is so tricky and inconvenient that we would hesitate to show this experiment at all had we not an easier method.

Before the lecture, fit several test tubes of 15 cm. length with soft corks and mark (with a china marking pencil, rubber band or label), the point at which they are half full.

Provide a glass trough about 15 cm. in diameter, half filled with a saturated salt solution. Dip beneath the surface of the solution as far apart as possible, two bent brass blow pipes which are attached respectively to the chlorine tank and to the hydrogen tank by rubber tubing. See illustration. Turn on the gases and allow the flow to continue until the air has been driven out and bubbles of the respective gases appear in countable succession.

Fill the test tube to be used with saturated salt solution. Invert it into the solution in the trough and hold it over the chlorine outlet until it is filled to the half volume mark. Then hold it over the hydrogen jet until filled. Place the stopper, small end up, on the floor of the hood and place the test tube securely on it letting it stand upright. Allow a minute to get diffusion of the gases.

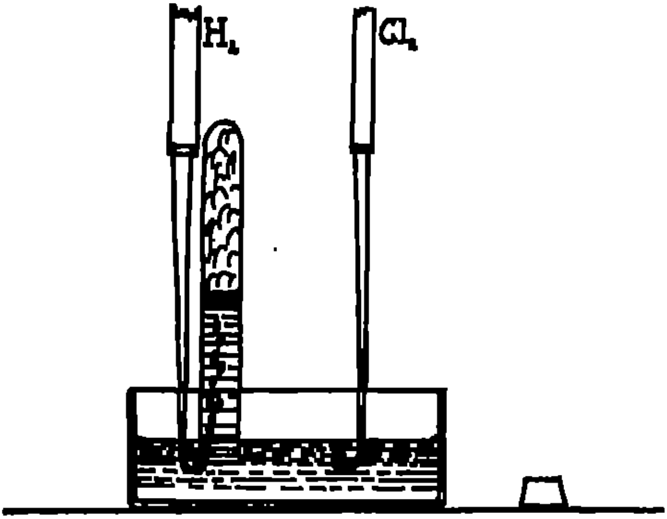


FIGURE 3

Shut off the flow of both the gases.

Take 10 cm. of magnesium ribbon, fold it into four parts, and, holding it with tongs light one end in a Bunsen flame. Hold the burning ribbon near the test tube of mixed gases until explosion ensues.

EXPERIMENT NO. 14

FIRE EXTINGUISHER

A very convenient form of lecture table fire extinguisher is made from a side neck suction flask, 17 cm. high and about 10 cm. in diameter.

A solid rubber stopper is fitted to the neck and a clamp taken from a soda bottle put on so that the stopper may be clamped in. These clamps may be bought at any five and ten cent store. They are attached to porcelain stoppers. The porcelain stopper is easily broken off. Onto the side neck is wired a 30 cm. length of rubber tubing, (thick walled preferred to prevent kinking) and the other end of rubber tubing is slipped over a glass nozzle the internal diameter of which at its outer end is about 3 mm. This nozzle should be securely wired into the rubber tubing, and is best slightly enlarged at its larger end.

A saturated solution of sodium bicarbonate is put in to such depth that the upper level is just below the side neck. A test tube of 10 cm. length is nearly filled with concentrated sulfuric acid. This is slipped gently while in an upright position into the flask. The depth of bicarbonate solution must be such that the test tube can lie obliquely across the flask and not have the bicarbonate solution flow into it while the flask is upright.

To demonstrate its action conveniently to the class, mount a large hydrometer jar vertically over the laboratory sink. Put the nozzle well up into this and then invert the flask. Such an extinguisher will shoot a stream 10 meters. If a large hydrometer jar is not available, take a length of large tubing, clamp it vertically and stopper the top end.

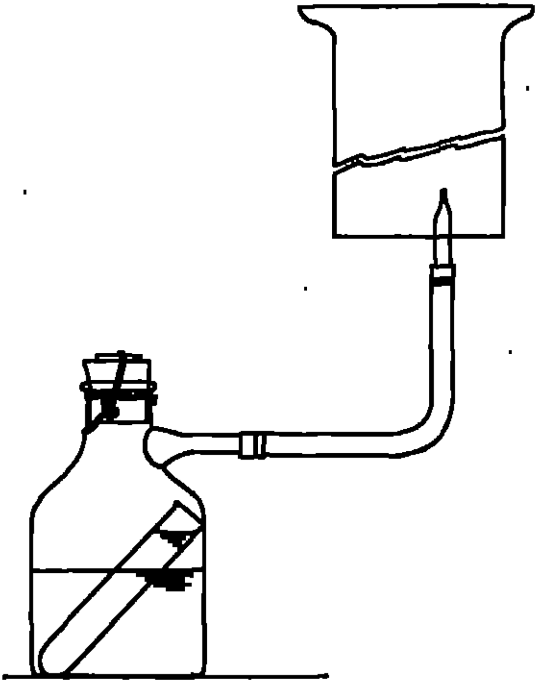


FIGURE 4

EXPERIMENT NO. 15

THE COMBUSTION OF PHOSPHORUS IN POTASSIUM CHLORATE

The action of phosphorus, a very vigorous combustible and potassium chlorate, a very vigorous oxidiser, can be very easily and safely shown in the following manner:

A 5-grain potassium chlorate tablet is placed on a piece of asbestos and onto it are dropped three drops of a solution of phosphorus in carbon bisulfide. This solution is made by dissolving a piece of phosphorus of the volume represented by a cylindrical stick of the material 2 cm. long by 3 mm. wide, in 2 cc. of carbon bisulfide. If the tablet saturated with this solution is left until dry, the explosive combustion will be spontaneous. If it is not desirable to wait for this to happen, after the lapse of three minutes the tablet may be touched with a long pointer which will cause the explosion. Or the tablet may have been placed on a square of asbestos which overhangs the lecture table so that on tipping it with a long pointer the tablet will fall off onto the floor. This generally insures its explosion provided the tablet is dry enough. If several of these tablets are prepared (not over five) and placed in a row 5 cm. apart, the explosion of one will determine the explosion of all the others.

The tablets called "chlorate of potash" may be obtained at any drug store.

EXPERIMENT NO. 16

AIR PRESSURE

The following method is a good one by which to demonstrate to students the great pressure exerted by the atmosphere. A Magdeburg hemisphere not smaller than 15 cm. diameter, with a perfectly round edge, is attached to an ordinary suction pump, by pressure tubing. The Magdeburg hemisphere may be set into a tripod. The rim of the hemisphere should be well

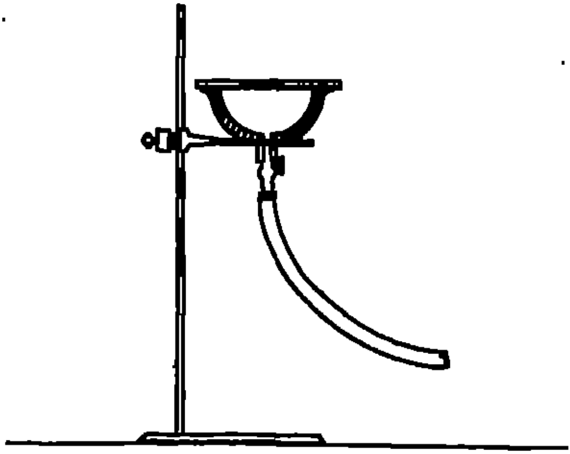


FIGURE 5

covered with vaseline. A piece of glass, preferably a fairly thin photographic dry plate, from which the film has been stripped by soaking in sodium hydroxide solution, is now placed on the vaselined hemisphere and held down rather firmly with the hand while the suction is applied momentarily. It is then possible to see if a good fit has been obtained. If the joint appears to be perfectly tight, put a box over the apparatus and turn on the suction again. In a moment, if everything is tight and the suction pump is a good one, the glass will break with such a crash as to reduce a large part of it to powder. Once in a while a piece of glass is found which is not plane enough to make a tight joint and if the experiment fails to work, this is presumably the cause. It is worth while having the students figure what the total pressure is on the top surface, if it is assumed that the pump removes all the air from below.

NOTE: A vacuum desiccator may be used in place of the Magdeburg Hemisphere, but being made of glass is more easily broken.

EXPERIMENT NO. 17

HYDROLYSIS OF SODIUM ACETATE

Sodium acetate, being a salt of a strong base and a weak acid, hydrolyzes when put into water to give a basic reaction.

That this reaction is favored by heat can be shown nicely by taking a very dilute solution of sodium acetate to which a few drops of phenolphthalein solution have been added. If proper strength has been chosen, 1.5 grams in 100 cc. no pink color is evident. If now the solution is heated, the pink color appears, and on cooling it disappears.

EXPERIMENT NO. 18

THE CHANGES IN AN AMMONIUM HYDROXIDE SOLUTION ON HEATING

If one drop of concentrated ammonium hydroxide is added to 100 cc. of distilled water and five drops of phenolphthalein solution added, the color will be pink, due to the ionization of the hydroxide.

If this solution is now heated, the pink color completely disappears. At first thought it would appear that this is due to the boiling away of the ammonia gas, but that such is not the case is shown on cooling, whereupon the pink color returns.

It seems to be the fact that heating favors the decomposition of the NH_4 ion and the formation of water molecules, leaving, while hot, chiefly a solution of ammonia gas in water which contains not enough hydroxyl ions to affect the indicator.

EXPERIMENT NO. 19

WOOD'S METAL

Wood's metal is easily made by putting into a sand crucible the following ingredients:

4 parts of bismuth by weight
2 parts of lead
1 part each of tin and cadmium

according to the well known formula and heating until the mass is all melted.

This alloy will melt at about 60° C. and this fact is shown on the lecture table to the best advantage if the metal is in stick form, the diameter of the sticks being about 3 mm. These sticks are easily molded by putting the Wood's metal in a deep dish containing boiling water whereupon it soon becomes liquid below the water. A glass tube whose internal diameter is 3 mm. is dipped into the liquid metal and suction is applied to the other end, the liquid metal moving up the tube.

Cold water is poured into the tube, whereupon the metal solidifies, and it is removed from the glass by breaking the glass away from it.

A stick so prepared is clamped so that the lower end is just above a flask in which water is made to boil. The steam from the flask will melt the stick of metal down like an icicle and the liquid metal will drop to the bottom of the flask.

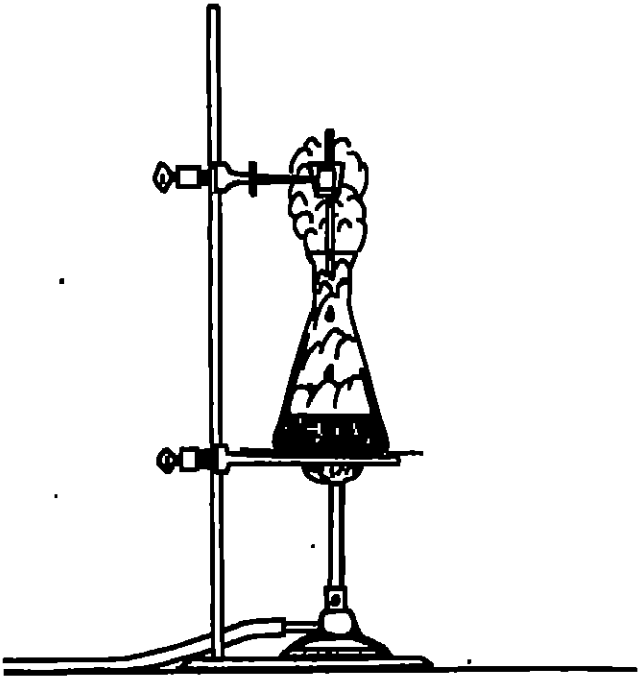


Figure 6

EXPERIMENT NO. 20

VAPOR DENSITY OF GASES BY EFFUSION

(Calculation of Molecular Weights therefrom.)

A student lamp chimney is fitted in its most constricted part with a No. 5 one-hole rubber stopper, placed in from the larger end. This stopper carries a tube about 12 cm. long projecting out of the larger end of the chimney, and having its outer end so nearly closed that gas flows through very slowly. This tube is made by rotating the squarely cut tube in a flame until the surface tension has constricted the opening to an extremely minute hole, which is still able to pass some gas. The chimney is counter weighted to make it sink in water, by filling the cup formed by the base of the chimney with water. Make a mark about 15 cm. from the smaller end and perpendicular to the length of the chimney. A single light stroke with a sharp file will make this mark.

A hydrometer jar 30 cm. high by 5 cm. in diameter is filled to overflowing with water. Set the hydrometer jar in a shallow pan to receive the overflow of water. The chimney with its counterweight of water is held just over the surface of the water in the hydrometer jar, the lower part of the chimney being filled with air. At a given instant, lower the chimney quickly until the wide part rests on the top of the hydrometer jar. Take the time required for the water to ascend exactly to the mark. Run a tube from a gas jet as far up into the chimney as may be, and allow gas to flow in for one quarter of a minute. This insures a tube full of gas free from air. Repeat the operations as described for getting the time required for air to flow through the minute opening, and record the time taken for the gas to flow.

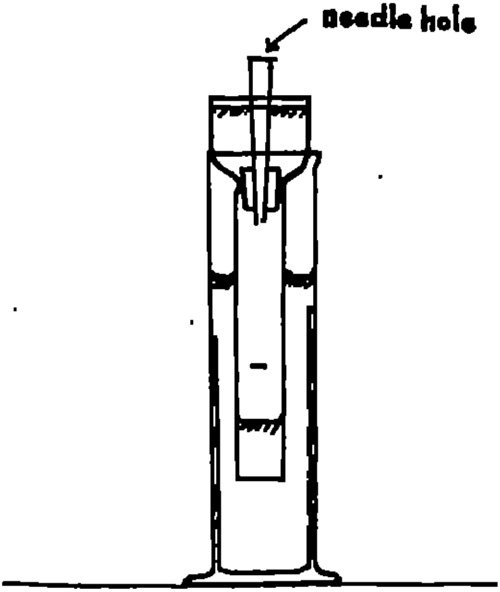


FIGURE 7

These two times are directly proportional to the square roots of the densities of the gases, provided the flow has been slow enough so that the time taken for the air is somewhere near five minutes. The tube with the small opening must be tried out carefully and if the time required for the air to flow is not about four or five minutes, it should be discarded.

$$\frac{t}{t'} = \frac{\sqrt{D}}{\sqrt{D'}}$$

The density of the illuminating gas is actually obtained at the works by a process similar to this and consultation with the chemist at the gas works will show you whether your results are approximately correct.

If hydrogen and oxygen are used instead of air and illuminating gas, the vapor density (or specific gravity) of oxygen may be determined with reference to hydrogen as the standard and from this the molecular weight of the gas may be obtained by multiplying by 2.

$$\text{Specific gravity of a gas (H standard)} = \frac{\text{mol. wt. of gas}}{2}$$

Any gas whose solubility in water is slight may have its molecular weight determined by this method.

EXPERIMENT NO. 21

CHARCOAL FILTER

A student lamp chimney is provided with a one-hole rubber stopper through the hole of which a glass tube about 6 cm. long projects. On this glass tube is placed a short length of rubber tubing closed by a pinch clamp. The chimney inverted is clamped to a ring stand. A layer of excelsior is packed in rather firmly to the depth of 2 cm. Fill the rest of the chimney up as far as the constriction with granular bone charcoal. Above the inverted chimney place a ring which is just smaller than the largest diameter of a 500 cc. flask. Fit this flask with a cork stopper through which a hole has been cut about 1½ cm. in diameter.

Fill this flask with a solution of methyl violet, which is very dilute, but has a decided color. Holding this at an angle of about 45° in the right hand, reach through the ring with the left hand and put the thumb of the left hand over the hole in the stopper. Invert the flask, setting it down into the ring and taking the left hand thumb away at the same time. The neck of the flask should project down into the base of the chimney at least 4 cm. Let the chimney fill with the methyl violet and then open the pinch clamp until the liquid flows out a few drops per second. It will be seen that this liquid contains no methyl violet. The charcoal may be renewed from time to time by taking it out and heating it in an iron dish with a tight cover for one-half hour. This method of showing adsorption by charcoal is much better than the old method of boiling the solution with charcoal before the class, because it can be prepared before the class comes in and will work automatically during the lecture hour.

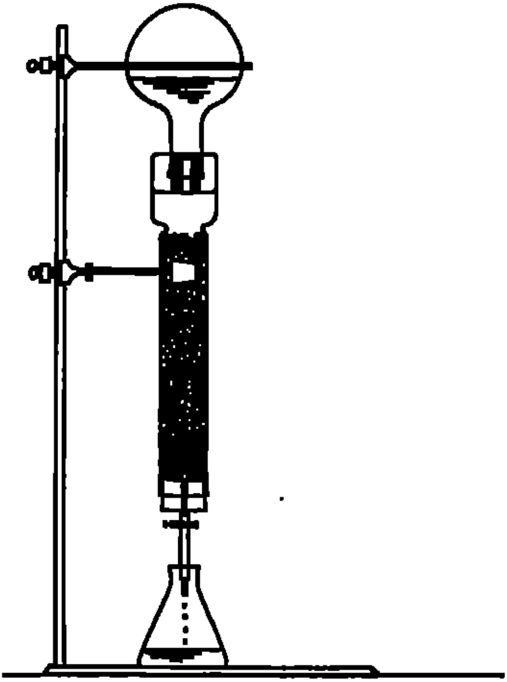


FIGURE 8

EXPERIMENT NO. 29

SOLUBILITY OF PHOSPHORUS PENTOXIDE

A precipitating jar containing 800 cc. of cold water has dropped into it a quantity of phosphorus pentoxide in powder form, this quantity being equal in bulk to that which may be contained in a 1 cc. space. The rapidity of its solution is so great as to produce a hissing noise such as is made by dipping hot iron into water.

Now contrast with this the solubility of the same substance when it is in an extremely fine state of sub-division.

Burn a piece of phosphorus in a small watch glass placed on a flat cork which is floating on water in a glass tank. Have provided a bell jar with a top opening which may be closed by means of a stopper, best a ground glass one, slightly vaselined. When the phosphorus is well kindled, lower the bell jar over it, the stopper being removed to allow the water level to remain the same inside as outside. The depth of water in the glass tank should be not less than 8 cm. Place the stopper in position and allow the phosphorus to burn as long as it will. The phosphorus pentoxide formed thus is an extremely fine powder, each particle being separated from its neighber by a film of air and each particle apparently adsorbing the air with great tenacity. As the particles fall, which they do only slowly, the adsorbed film of air seems to prevent their speedy solution. That the slowness with which the solution is effected is due to something more than the slowness with which the particles fall, is amply demonstrated by covering the bottom of the bell jar with a glass plate, inverting it with the water still in and shaking it vigorously. Even with all this thorough mixing of the water with this white smoke, there is still a very apparent reluctance of the particles to go into solution.

EXPERIMENT NO. 23

OXIDATION OF AMMONIA

The oxidation of ammonia to nitric acid is very easily and simply shown by putting about 50 cc. of the strongest ammonium hydroxide into a test tube whose length is about 20 cm. and whose diameter is about 4 cm. The test tube is clamped upright and oxygen from a tank is bubbled through the ammo-

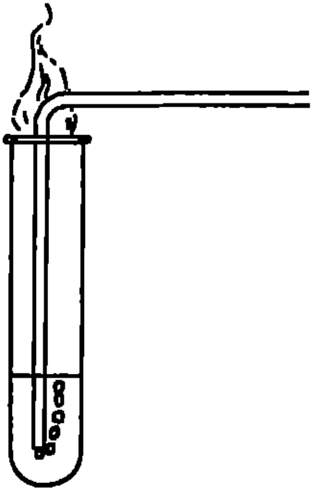


FIGURE 9

nium hydroxide. By proper regulation of the flow of the oxygen the bubbles coming up through the ammonium hydroxide will acquire enough ammonia gas to become explosive. This mildly explosive mixture may be lighted at the top of the test tube and will generally strike back to the surface of the hydroxide where the bubbles will continue to burn at the surface. Do not try to do this in any vessel except one with parallel sides. If it is done in a flask the explosion is sometimes severe enough to burst the flask.

EXPERIMENT NO. 24

SALT FROM SODIUM ACID SULFATE

In the manufacture of hydrochloric acid, by the addition of one molecule of sulfuric acid, to one molecule of salt, sodium acid sulfate is produced together with the gaseous hydrochloric acid, and most students think that the reaction will go completely to an end because of the volatility of the hydrochloric acid. This is practically true, provided the sulfuric acid used is not too dilute. But that this reaction $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$ is really a reversible one, can readily be shown. A saturated solution of sodium acid sulfate is poured into a tall footed test tube and some concentrated C.P. hydrochloric acid is added. A cloud of salt crystals will settle out. This experiment is also a splendid illustration of mass action.

EXPERIMENT NO. 25

SOLID ALCOHOL

A saturated solution of calcium acetate is made up and filtered. Four cc. of this solution are poured into a test tube which can hold about 75 cc. Fifty cc. of alcohol are poured in and the test tube quickly inverted several times to mix the liquids thoroughly. In a moment the mass becomes so firm that the test tube may be inverted without spilling any. This "solid alcohol" may be removed from the test tube and burned and it will be noticed that the mass does not melt down as is the case with some other varieties of "solid alcohol".

In reality the alcohol is still liquid but is held in the meshes produced by the crystals. If some of the "solid" is kept undisturbed for several days the crystals will have settled to the bottom of the container and the alcohol will be clear again.

EXPERIMENT NO. 26

AMMONIA FROM COAL SOOT

That the burning of coal, which contains sulfur and nitrogen and the elements of water, produces from these, ammonium sulfate, can easily be shown. Some coal soot (about one handful), is mixed with an equal bulk of slaked lime and enough water is added to make the mass moist but not pasty. This is put into a beaker and across the top is placed a sheet of wet, red litmus paper. The beaker is then warmed very gradually either high over a small flame, or by being put on a cold electric stove which is turned on to the full heat. The heating by this method will be very gradual. The litmus paper will soon turn blue from the ammonia evolved, and the presence of ammonia gas may also be shown by holding over the open top of the beaker, a stopper wet with concentrated HCl.

It is this ammonium sulfate in the soot which makes it so valuable as a fertilizer, especially for lawns. Experiments at Rhode Island State College have shown that a practically weedless lawn can be produced by fertilizing with ammonium sulfate. This substance produces an acid condition in the soil by hydrolysis, and grasses, especially Rhode Island Bent, are tolerant of an acid soil, and most weeds are not.

EXPERIMENT NO. 27

RATE OF DISSOLVING

Two hydrometer jars of equal size and about 30 cm. high are filled nearly full of clear water. A test tube of 1.5 cm. diameter is heated uniformly at a distance of 5 cm. from the open end and drawn out to a blunt conical constriction whose smallest part is about 2 mm. in diameter. The tube when cooled is cut at the point of greatest constriction and the broken edges of the part which was the top of the test tube very carefully fire polished. Around the top of the

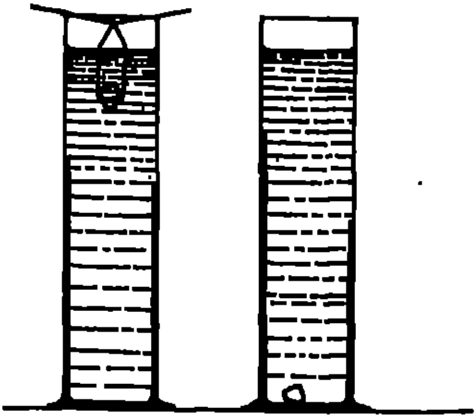


FIGURE 10

test tube wrap a turn of wire (preferably lead) and twist the ends to bind it firmly to the glass, carrying the free end up and over the top of the test tube to make a handle when tucked under the wire loop at the side opposite the twisted part.

Select two crystals of copper sulfate of equal weight, and have one of such shape that it will easily slip into the prepared test tube. Put the crystal into the test tube and slip a glass rod a little longer than the diameter of the hydrometer jar through the handle. Drop one crystal into one of the jars, and hang the test tube containing the other on the rim of the second jar. The suspended crystal will dissolve in a short time, generally less than the lecture hour, and the crystal at the bottom will take days to dissolve completely.

NOTE: This experiment can be given out to all the members of a laboratory division by substituting 15 × 2 cm. test tubes for the hydrometer jars and by using a very small test tube drawn out to hold the suspended solute, hooking the wire over the edge of the larger test tube. At Brown University "chlorate" of potash tablets are used as the solute, because of the ease of getting equal weight pieces thereby. They may be purchased at any drug store at about $1.00 a thousand.

EXPERIMENT NO. 28

AMMONIUM AMALGAM

Sodium amalgam is first made by pouring into a heavy porcelain mortar, about 10 cc. of mercury. Pieces of sodium which are spherical and have a diameter of about 5 mm. are placed out on a piece of filter paper. One of these is struck with the pestle so that the sodium sticks to the rounded end of the pestle. The sodium thus held is plunged beneath the surface of the mercury until reaction occurs. This slightly warms the mercury and the next piece put in similarly will react more quickly. Continue adding pieces of sodium until the mass is of a thick creamy consistency which upon cooling will become hard.

Make up now a saturated solution of ammonium chloride and pour 50 cc. of this into a glass crystallizing dish. Break up the sodium amalgam into four or five pieces and put them into the ammonium chloride solution. The reaction supposed to go on is this

$$NaHg + NH_4Cl = NaCl + NH_4Hg$$

The last substance is called ammonium amalgam and in it the ammonium group may be considered temporarily at least, to be metallic. It rapidly decomposes producing ammonia (NH_3), hydrogen, and mercury. To demonstrate this put some of the spongy ammonium amalgam into a large test tube which is covered with a small watch glass. Let the amalgam decompose for a few moments and then apply a light to the mouth of the test tube whereupon a flash of fire will indicate the hydrogen. Then hold in the escaping vapors a piece of red litmus paper which will turn blue showing the presence of ammonia, which may also be shown by holding the stopper from the concentrated hydrochloric acid bottle near the mouth of the test tube, whereupon white fumes will be formed consisting of ammonium chloride.

EXPERIMENT NO. 29

SOLUBILITY OF GLASS

Take a perfectly clean mortar and pestle and in it grind a perfectly clean test tube until a fine powder results. Have a precipitating jar (or large test tube) nearly filled with water, to which have been added 8 or 10 drops of phenolphthalein solution. Into this pour the powdered glass, whereupon a pink coloration will be observed, indicating hydrolysis of the glass, which could not have taken place without solubility.

Glass wool such as is used for filtering also shows this solubility well.

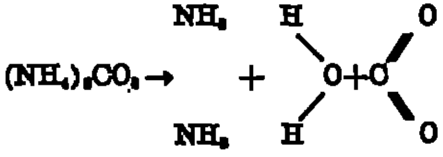
The argument that free alkali in the glass is the cause of the pink coloration seems to be refuted by the fact that after repeated washings, glass wool still shows an effect on the indicator.

Commercial powdered glass used as above gives a very decided color test.

EXPERIMENT NO. 30

THE SPONTANEOUS DECOMPOSITION OF AMMONIUM CARBONATE

A lump of crystalline ammonium carbonate of approximately 200 cc. volume is placed upon a plate of glass and counterpoised on a lecture table balance, at the beginning of the lecture hour. Before the end of the hour it will be seen that much of the crystal has disappeared as volatile matter and before the class has been dismissed, the plate with the piece of carbonate on it may be placed in a conspicuous location and the attention of the students called to the fact that it will sooner or later completely disappear, since all of the products of the decomposition, ammonia, carbon dioxide, and water, are gaseous.



EXPERIMENT NO. 31

DECOMPOSITION OF AMMONIUM CARBONATE

Ammonium carbonate is used as a fire extinguisher and its action in this capacity is easily shown. When heated it decomposes into products all of which are volatile, namely, carbon dioxide, water vapor, and ammonia. All of these are incombustible and serve to put a blanket around a fire and prevent oxygen from carrying on combustion.

Select a deep, narrow beaker of 20 cm. height by 10 cm. width. Into the bottom of this put a single large lump of ammonium carbonate. Warm this very gently high over a small flame, keeping a glass plate over the top. The warming may be very advantageously done on an electric hot plate set at a low point. After warming has continued for 10 minutes it will be found that a lighted taper thrust into the beaker will be extinguished and water vapor will have condensed on the sides of the beaker.

If the cover is now removed, the whole lump will soon disappear leaving no solid residue whatever.

An Erlenmeyer flask is also sometimes used for this experiment and need not be covered with the glass plate.

EXPERIMENT NO. 32

GOLDSCHMIDT REACTION

Various methods have been used for showing the Goldschmidt reaction to an audience, most of which have some serious objection.

The following method seems to be a very satisfactory one and certain to work as expected. A small sand crucible (Hessian) which can hold about 30 cc. has a hole about 3 mm. in diameter bored through the bottom. This can be done very easily with a three cornered small triangular file from which the filing surface has been ground off, leaving sharp angles. The crucible is mounted in a small ring on a ring stand. Underneath is placed a large battery jar in which there is a layer of sand about 5 cm. deep. Another larger crucible about 12 cm. high is embedded firmly in the sand and a small hemispherical thin iron dish is placed upright on the crucible.

Water is poured into the battery jar until the iron dish is just covered and the whole allowed to settle. If the sand has been thoroughly washed, there should be practically no turbidity. The small crucible is filled nearly to the top with the commercial thermite. The granules of this are of such size that they will not fall through the hole in the crucible.

A starting mixture is made up of ten parts barium peroxide and one part granulated aluminium by weight. A small amount of this starting mixture, enough to make a cone 1 cm. high, is poured on the top of the thermite.

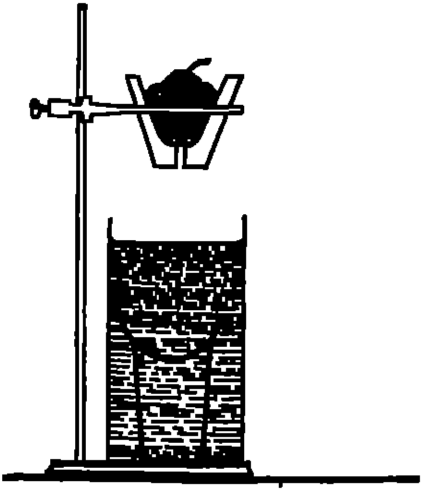


Figure 11

Take a piece of thin magnesium about 10 cm. long. Double this and then double again. Put this fourfold piece slightly twisted together into the little heap of starting mixture. Have a long handled taper, at least a meter in length, and with this light the magnesium ribbon. If all goes well the melted white hot iron will flow through the hole in the crucible, down into the water and will pass through the iron dish. It is never safe to have this on the lecture table without putting an asbestos mat over a considerable part of the table, nor is it safe to have students very close.

The hole in the crucible may be bored by hand with a screw driver of the right size.

EXPERIMENT NO. 33

INFLUENCE OF TEMPERATURE ON SPEED OF A REACTION

A convenient way to show that the speed of a reaction is hastened by an increase in temperature is as follows:

A solution of potassium permanganate is made up of such concentration that it is a dark purple in color. About 1 gram of the salt per liter of water is sufficient. To this solution should be added 100 cc. of 1-5 sulfuric acid. Exactly 200 cc. of the so prepared solution is poured into each of two flasks and one of these is heated nearly to the boiling point. A photographic developing solution is now made up from a commercial tube of MQ developer which may be bought in any photographic supply store. The developing solution is now diluted to such strength that on trial previous to the lecture, 200 cc. of it will reduce the cold potassium permanganate solution in about 5 minutes to a perfectly colorless solution.

To demonstrate the effect of temperature now, put into each of two hydrometer jars, 200 cc. of the developing solution and simultaneously into each of the hydrometer jars, pour 200 cc. of permanganate solution, into one the hot solution and into the other the cold solution. The hot solution will be almost immediately decolorised but the cold one will take around 5 minutes if the solutions have been made as directed.

EXPERIMENT NO. 34

ACTION OF WATER ON LEAD PIPES

The well known fact that soft water attacks lead pipes and leads to lead poisoning, but that hard water has little solvent action on lead, can be nicely shown in the following manner:

Two similar glass stoppered bottles have put into each, a piece of lead pipe which has been scraped clean. One bottle is filled with distilled water and the other with hard water. The action of the soft water (distilled) will be very apparent after the lapse of twenty-four hours especially if the bottles have been placed in a warm location. The distilled water will become cloudy and a white sediment will collect on the bottom and side of the bottle. That the lead has actually gone into solution in the soft water but not in the hard water, can be shown to the class by taking out samples from the two bottles and adding a solution of ammonium sulfide. The solution from the distilled water bottle will turn brown while the other one remains colorless. A piece of lead pipe which has been kept in distilled water for about five years has produced a white sediment so abundant that on shaking the bottle a milky suspension is produced capable of being shown to a large class.

It is easier for lecture table demonstrations, to use the solution of ammonium sulfide than it is to run in gaseous hydrogen sulfide.

EXPERIMENT NO. 35

DIFFUSION OF AMMONIA AND HYDROGEN CHLORIDE

It is a common thing to try the experiment of holding two stoppers taken from concentrated hydrochloric acid and concentrated ammonia bottles, and holding them within about 5 cm. of each other, to show the formation of ammonium chloride in the air between them. But much more can be shown than the simple formation of the ammonium chloride. NH_3 "gaseous" has a density of 8.5 while the hydrogen chloride "gaseous" has a density of 18.25, both densities being referred to hydrogen as a standard.

Since light gases diffuse more rapidly than do heavy ones, the ammonia should travel toward the acid stopper faster than the hydrogen chloride travels toward the ammonium stopper. This will be seen to be borne out by experiment for when the two stoppers are held within about 5 cm. of each other, the fumes of ammonium chloride will be seen to form on the acid stopper.

The vapor tensions of the two solutions, no doubt, have some effect upon this.

EXPERIMENT NO. 36

FREEZING WITH AMMONIUM NITRATE

While it is frequently shown that the solution of many solid substances produces a considerable lowering of the temperature of the solution, very few directions for performing this experiment before a class show that ice may actually be formed by the

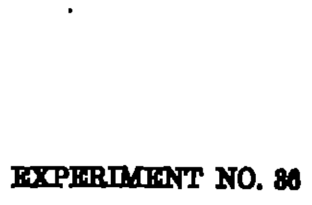


FIGURE 12

solution of a salt in water. A box about 30 cm. × 40 cm. is placed bottom up on the lecture table and in the center of the bottom about 2 cc. of water are placed. A 400 cc. beaker of thin glass is placed upon this water. If necessary a little more water is added to make sure that the whole of the bottom of the beaker is wet. The beaker now has placed in it 100 grams of granular ammonium nitrate. Care should be taken not to spill any of the nitrate onto the box

that a solution whose freezing point is lower
ter would be formed under the beaker. Into
ular ammonium nitrate pour all at once 100
ater, stirring with a wooden stirrer or a horn
In a half minute the beaker will be frozen
o the box and the box may be lifted from the
able using the beaker as a handle.
eason for setting the beaker exactly in the
the box is now apparent.
olution should be returned to a residue bottle
er recrystallised.

for fear that a solution whose freezing point is lower than water would be formed under the beaker. Into this granular ammonium nitrate pour all at once 100 cc. of water, stirring with a wooden stirrer or a horn spatula. In a half minute the beaker will be frozen solidly to the box and the box may be lifted from the lecture table using the beaker as a handle.

The reason for setting the beaker exactly in the center of the box is now apparent.

The solution should be returned to a residue bottle to be later recrystallized.

a few moments by putting commercial sodium fluoride (or ammonium fluoride) solution in a lead dish to the depth of 5 cm. and clamping the electric light bulb vertically in the liquid.

A 10 minute immersion is sufficient to give a fine matted surface.

EXPERIMENT NO. 38

THE AMPHOTERIC CHARACTER OF ZINC HYDROXIDE

Put 10 grams fused zinc chloride into 300 cc. of water in a tall jar, stirring or shaking until the chloride has disappeared and a flocculent precipitate of zinc hydroxy-chloride has been produced.

$$ZnCl_2 + H_2O = HCl + Zn(OH)Cl$$

This is an excellent way to show hydrolysis.

Add concentrated HCl a little at a time until the precipitate just disappears.

$$Zn(OH)Cl + HCl = ZnCl_2 + H_2O$$

Next add a concentrated sodium hydroxide solution a little at a time until a thick paste of zinc hydroxide has been obtained.

$$ZnCl_2 + 2\,NaOH = Zn(OH)_2 + 2\,NaCl$$

Continue to add the sodium hydroxide until a clear solution results.

$$Zn(OH)_2 + 2\,NaOH = Na_2ZnO_2 + H_2O$$

Next add concentrated hydrochloric acid a little at a time until the precipitate reappears.

$$Na_2SnO_2 + 2\,HCl = 2\,NaCl + Zn(OH)_2$$

Continue to add the acid until the precipitate dissolves.

$$Zn(OH)_2 + 2\,HCl = ZnCl_2 + 2\,H_2O$$

It is possible to repeat these operations with the solution last obtained as a starting point.

EXPERIMENT NO. 39

THE COMBUSTION IN A FURNACE

A very easy way to show the combustion which takes place in a coal fire is as follows:—

A sand crucible about 15 cm. in height has a hole bored nearly through the bottom starting from the outside, the hole being of such diameter that it will just fit snugly on the tube of a Bunsen burner. This hole is bored to such depth that the remaining thickness of material is about 4 mm. The hole is continued through in much smaller diameter by driving a wire

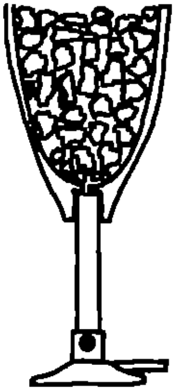


FIGURE 12

nail through the remaining thickness of the bottom of the crucible. This crucible now will sit firmly on a Bunsen burner which is used as a stand. Start a fire in the crucible by first dropping in several matches, of which one is lighted, and blowing a current of oxygen from a tank (which is connected with the Bunsen burner by a rubber tube) up through the burning kindling. Now add hard coal in pea-coal size gradually until the crucible is full, keeping the current of oxygen still passing through.

When the fire is burning brightly the oxygen supply is cut off and a gentle current of carbon dioxide from a tank is passed through the hot coal, whereupon the reduction of the carbon dioxide to carbon monoxide takes place and the blue flame of the carbon monoxide burns over the surface of the coal. It is best to have both tanks, the oxygen and the carbon dioxide connected at the same time to the Bunsen burner, using a Y tube to accomplish this.

NOTE: The hole may be easily bored in the sand crucible by hand, using a screw driver of the proper width. It takes only a few moments to bore through a 2 cm. thickness. To prevent back pressure in the apparatus it is best to remove the tip in the inside of the Bunsen burner and thus allow a free passage of gas.

EXPERIMENT NO. 40

THE OXIDATION OF SULFUR DIOXIDE WITH SODIUM PEROXIDE

A pile of equal parts of dry sawdust and dry powdered sodium peroxide is placed on a sheet of asbestos. For an ordinary sized lecture room a pile about 5 cm. in diameter and 1 cm. high is sufficient. Let a jet of sulfur dioxide from a tank of the gas impinge on this heap and immediately a very brisk fire ensues.

This shows how easily a fire might be caused in a laboratory if some of the peroxide was spilled on a wooden shelf and a sulfur dioxide tank near by happened to be left running or leaked.

If to another heap a few drops of water are added fire is immediately kindled. Great care should be exercised in dispensing sodium peroxide to students and under no case should it be left in contact with carbonaceous matter in the open. It is hygroscopic and when moist is likely to set fire to combustible material. Laboratory fires can easily be started by the storage of the peroxide on filter paper in the lockers.

EXPERIMENT NO. 41

THE DESIZING OF CLOTH

The modern method of getting rid of starch on cloth before it is put through the finishing processes is to convert the insoluble starch to glucose by means of an enzyme. The glucose being soluble can then be washed away.

The enzyme is contained in Diastafor or Diax sold commercially for the purpose.

It is possible to make a quick lecture demonstration of this process which in actual practice takes four hours.

Make up a starch solution by mixing 5 grams of starch with a little water to make a creamy mass, and pour this into 500 cc. of boiling water.

Take two hydrometer jars of 500 cc. capacity. Put 400 cc. of water in each.

Make a solution of tincture of iodine according to the U. S. Pharmacopoeia and of this mix 5 cc. with 20 cc. of water. Put 1 cc. of this diluted tincture of iodine into each hydrometer jar and to each jar add also 5 cc. of the starch solution. Mix the solutions thoroughly to get uniform blue color in each jar.

To one jar add 5 cc. of a solution of Diastafor made by adding 5 cc. of the commercial Diastafor to 200 cc. of water. If the temperature of the water is 20° C.

the starch will all be converted to sugar in about a minute and the blue color will all disappear.

Water that is luke warm (85°) will give a much quicker reaction.

EXPERIMENT NO. 49

THE ORDER OF MIXING

Increasing attention is being given to the order of mixing chemicals. The form in which precipitates occur and their usefulness or harmfulness for certain purposes depends on which of the reactive substances is poured last into the reaction vessel. This has such important practical bearing that the government bulletins dealing with the mixing of sprays for insect control stipulate in which succession the various ingredients shall be added.

To show this easily to a class, provide two similar 30 cm. hydrometer jars and two similar test tubes of 10 cm. length. Nearly fill the jars with muddy water and then to one add a test tube of saturated alum solution and to the other a test tube of concentrated ammonia solution. Using the test tubes for the same substances for which they were last used, add now to the jar containing the alum solution a test tube of ammonia and to the jar containing the ammonia solution, a test tube of alum.

Mix the contents of the jars well by several inversions of each, holding the palm of the hand over the mouth of the jar as it is inverted.

Set them aside for a few moments when it will be seen that the clarification is rapid in the case where the ammonia was added last and very slow and incomplete in the other.

EXPERIMENT NO. 43

WHITE SULFUR

To make a quick demonstration of the formation of finely powdered white sulfur buy the commercial "lime-sulfur" used for spraying trees. This is of 33° Beaumé. The experiment is best shown by putting a dilute solution (10 cc. of the lime-sulfur in 400 cc. of water) into a 500 cc. hydrometer jar, and adding 25 cc. of concentrated hydrochloric acid. It will be noticed that at the instant of formation the sulfur is practically white, but it rapidly turns yellow on standing. A solution of photographer's hypo (10 grams of the crystals in 400 cc. of water) will precipitate out nearly white sulfur on the addition of 5 cc. of concentrated hydrochloric acid. The precipitation at this dilution is slow and makes a very interesting demonstration.

EXPERIMENT NO. 44

LIQUEFIED AMMONIA

If a tank of anhydrous ammonia is available, the liquid may be obtained from it and shown to the students at the lecture table very easily. The tank is tipped so that the outlet is lower than the other end and a rubber tube fastened to the outlet leads the liquid into a liter Dewar Bulb. The liquefied ammonia will keep for hours in one of these, which, of course, must not be stoppered tightly.

DO THE FOLLOWING EXPERIMENTS IN THE HOOD!

If a piece of thin rubber tubing is dipped into the liquid and left for a few minutes, it will be frozen so hard that it becomes brittle and on being hit with a hammer will fly into bits.

If a globule of mercury be poured into a large watch glass (10 cm. diameter) and liquid ammonia poured on the mercury will be frozen hard.

Pour some of the liquid into a 500 cc. beaker which is set in a small pool of water on a board. The beaker will soon freeze to the board.

EXPERIMENT NO. 45

TIME REACTION OF IODIC ACID

The time reaction of iodic acid, which in itself is a startling experiment, can be made to show very conclusively the effect of dilution on the speed of a chemical reaction.

Solutions are made up as follows: Dissolve 0.4 grams of sodium iodate (or .44 grams of potassium iodate) in a few cubic centimeters of water. Pour this into a flask and add water to make the total volume 200 cc. Dissolve 0.2 grams of sodium sulfite, chemically pure $Na_2SO_3 \cdot 7\ H_2O$, in 50 cc. of water. To this add 1 cc. of sulfuric acid. (1 part C.P. acid to 50 parts water by volume.) Mix 2 grams of starch with enough water to make a creamy paste, containing no lumps and pour this into 100 cc. of boiling water. Add the starch solution to the sulfite solution and dilute with water until the volume of this mixture is 200 cc. Cool these solutions to room temperature.

If 100 cc. of each solution are poured together, and thoroughly mixed, it will be found that the mixture will change to a dark blue color almost instantaneously in about 45 seconds, the exact time depending upon the temperature. The reaction goes more rapidly at higher temperatures. The explanation of this reaction is somewhat like this: Iodic acid is HIO_3, which may be made by this reaction:

$$H_2SO_4 + 2\ NaIO_3 = 2\ HIO_3 + Na_2SO_4$$

If iodic acid reacts with sulfurous acid, the equation is this:

No. 1 $3\ H_2SO_3 + HIO_3 = HI + 3\ H_2SO_4$

But this reaction also goes on:

No. 2 $HIO_3 + 5\ HI = 3\ H_2O + 3\ I_2$

Hence since starch paste is a test for iodine (giving a blue color) we should get a blue color if we add sulfurous acid to a solution of iodic acid. But the equation No. 2 apparently does not take place until all of the sulfurous acid has been used up (3 molecules) by one molecule of iodic acid or until equilibrium has been reached in this reaction.

If now there is an excess of iodic acid it will unite with some of the hydriodic acid formed and iodine will be set free (equation No. 2).

The second reaction, then, has to wait for the first one to finish, and the time required, at any given temperature depends on the dilution of the solution used.

Call the concentration of this solution which reacts to give the blue color in about 45 seconds, the 100 per cent concentration. Take exactly 20 cc. of each solution and add 80 cc. of water to each. The solutions are now 20 per cent as concentrated as they were. Pour these solutions together and take the time required for the blue color to appear. Set this mixture aside since it takes nearly 40 minutes to react.

Do the same thing with 40 cc. of each solution and

60 cc. of water, making 60 per cent concentration; and 80 cc. of each solution and 20 cc. of water, making 80 per cent concentration.

Record the time taken by each of these.

Plot out on the blackboard a curve putting concentrations as abscissae and times as ordinates respectively, thus showing graphically the effect of dilution on concentration.

This time reaction also lends itself well to showing the effect of temperature on speed of reaction, provided the temperatures are low. When the temperature is high the starch hydrolyses to such an extent that no blue color is produced.

EXPERIMENT NO. 46

EXPLOSION OF HYDROGEN-OXYGEN MIXTURE

(Knallgas)

The explosion of a mixture of two parts hydrogen and one part oxygen, can be safely and very simply shown, with the device illustrated.

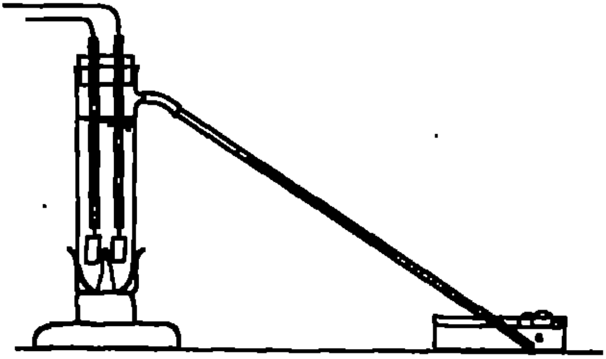


FIGURE 14

A side-neck test tube, 14 cm. long, and 2 cm. in diameter, is inserted in a test tube holder or is clamped upright just above the table. A 2-hole rubber stopper fitting the test tube carries glass tubes which have platinum wires about 1 cm. in length sealed into the ends in such a way that about half the wire is inside the tube and the other half outside. To these platinum wires have been welded pieces of sheet platinum about ⅛ cm. by 2 cm. in dimension. It is a simple matter to heat the wire and platinum foil to white heat while they are in the proper position for welding and to cause them to adhere by one smart blow with a light hammer.

The tube should project through the stopper to such a distance that the platinum foil will be about 2 cm. from the bottom of the test tube. Mercury is poured into the tubes to about 1 cm. depth. The side neck has fastened to it by a rubber connector, the inside of which has been coated with vaseline, a tube about 20 cm. in length and 7 mm. external diameter. In the upper part of this tube small granules of soda lime are loosely packed. The vaseline prevents the disintegration of the rubber by the ozone formed.

Sulfuric acid, 1 part acid to 10 parts water, is put in until within 2 cm. of the side-neck. Care must be taken that the platinum electrodes do not touch. Wires from the source of direct current having a voltage of about 8, are inserted into the tubes so that they dip into the mercury. Electrolysis will begin, and since the whole apparatus is very small, it takes only a very short time to displace all the air. After it has run for 2 or 3 minutes, dip the end of the delivery tube into a soap solution contained in a shallow evaporating dish or crystallizing pan, wait until a fairly large bubble has been blown, and then remove the dish containing the bubble to a distance of at least 3 feet and apply a light. If things have gone well there will be no doubt of the violence of the explosion of this mixture.

The soda lime granules prevent the passage of sulfuric acid, which might be mechanically carried over. If any got over the bubbles would be destroyed.

EXPERIMENT NO. 47

PERCENTAGE OF OXYGEN IN AIR

One of the older methods of doing this experiment advocated the use of a quart fruit preserving jar in which phosphorus was burned while the lid was tightly clamped on. This always gave more or less difficulty because the heat due to the combustion of the phosphorus expanded the air to such an extent that some air almost invariably leaked out. This is due to two causes: first that fruit jars are not designed to withstand pressure from within but only from without; and second that the area of the cover is very large and hence very secure fastening is demanded. These objections are easily overcome by substituting for the fruit jar a clear glass soda bottle with a clamp stopper. This is designed primarily to withstand pressure from within, and has a small mouth, thus overcoming the objections to the fruit jar.

The holder for the phosphorus is held by a cork of such size that it will just fit firmly into the neck of the bottle and can be pushed in about 5 cm. This cork should have a notch cut lengthwise in it, and a hole in it to hold a glass tube drawn out as illustrated to form a holder for the piece of phosphorus. This should be about 1.5 cm. The phosphorus in its holder is now thrust up into the inverted bottle and ignited by concentrating the rays of the sun or the rays from an arc light on it until it takes fire. The combustion may also be started but less quickly, by placing the bottle in such position that any source of heat will raise its temperature gradually (e.g. on a radiator).

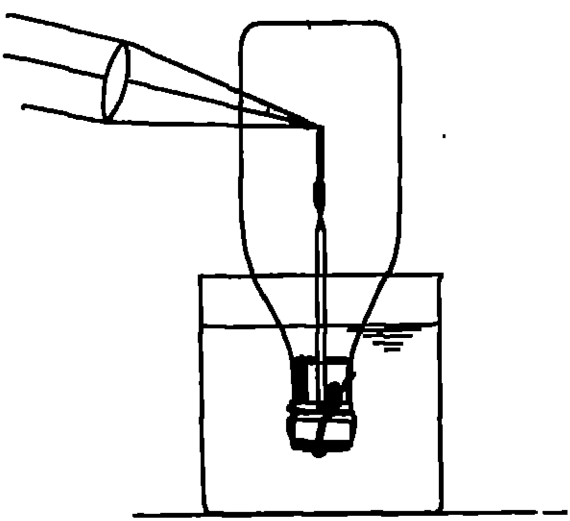


FIGURE 15

After the combustion has ceased the bottle is opened under water, the levels adjusted and the water which has been sucked in measured, leaving the phosphorus holder still in the bottle.

The bottle is now filled with water, the stopper clamped in position to force out any excess and the volume of the bottle determined by measuring this amount of water. This method is very simple, easily understood, and is practically certain.

Both volumes are then reduced to standard conditions and the percentage of oxygen in the air obtained by the formula

$$\frac{\text{Vol. air} - \text{Vol. residual gas}}{\text{Vol. air}} = \text{Per cent Oxygen}$$

EXPERIMENT NO. 48

THE STABILIZING OF FOAM

The fire fighting method which uses fire foam has a counterpart in some of the modern baking powders. When baking powder is put into dough, the albuminous compounds present form a protective coating around the bubbles of carbon dioxide and produce a much more lasting foam than is produced by the baking powder mixed with water alone.

As a talking point to be used by demonstrators, however, some of the present day baking powder manufacturers are putting in a small percentage of egg albumen which, when the baking powder is demonstrated, produces a very lasting foam to the economic detriment of the rival baking powder, which may produce as much gas, but whose foam is not permanent. The rival baking powder may, however, produce exactly the same results when mixed with the dough.

Procure a sample of baking powder (or make one up) known to contain no albumen. Powder a very small amount of egg albumen (1 gram for 100 grams of baking powder), and add this to a part of the sample. If, now, parallel experiments are carried out with these two baking powders, taking 10 grams of each in tall precipitating jars and adding 5 cc. of water to each, it will be shown that a lasting foam will be produced with the one containing the egg albumen and the foam produced by the other will disappear almost at once. The one which has the albumen in it may be completely inverted without spilling a drop. This is a splendid illustration of the application of colloid chemistry to a commercial product, but it is valueless as far as the bread product is concerned, since there are already albuminous substances in the flour and none need to be added.

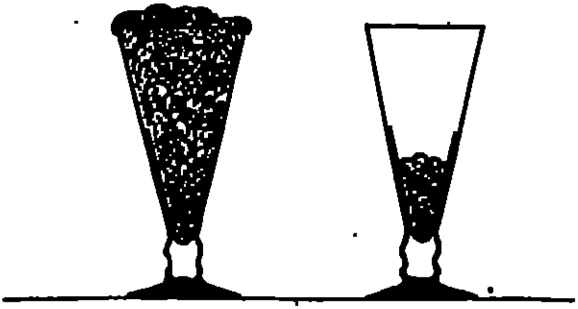


FIGURE 16

EXPERIMENT NO. 49

DIFFUSION OF GASES

The difference in rate of diffusion of gases of different densities through a porous wall can be very easily and convincingly shown by means of the apparatus illustrated.

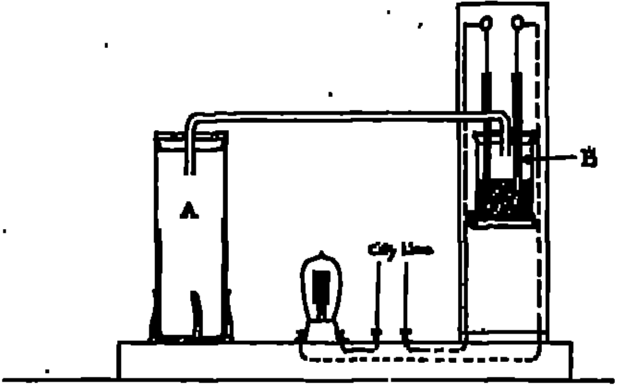


Figure 17

The porous cup A has a tight fitting cork stopper, which has been soaked in melted paraffin to close its pores. The small beaker B is clamped to the upright and is closed by a 3-hole rubber stopper, one hole having been enlarged to take a piece of glass tubing whose external diameter is 1 cm. and which is 7 cm. long. In another of the holes a piece of tubing of 5 mm. external diameter and 7 cm. length is placed. Binding posts are fastened to the upright support, the holes through them being vertical and as far apart as are the centers of these tubes just mentioned. Pieces of lead wire (30 ampere fuse wire) are now passed through the binding posts and down into these glass tubes, the piece passing through the smaller glass tubes projecting about 5 mm. below the tube and the one passing into the larger tube stopping short of the bottom of 6 mm. It is essential that the wire in the larger tube be centrally placed. Through the third hole of the stopper dilute (1–5) sulfuric acid is poured until the bottoms of both glass tubes are covered to the depth of 4 mm. The glass tube connecting the porous cup and the beaker passes through the third hole in the stopper. Wires of sufficient size to carry the city lighting circuit (or battery current, if that is to be used) are brought down to the base board from the binding posts and an electric light socket is wired in series with these terminals. The electric light bulb should be of a voltage suitable for the current used and either binding posts or plug connectors should be attached for connecting to the circuit used.

If now a stream of illuminating gas or hydrogen is directed at the porous cup from a distance of about 10 cm. the light gas will go through the pores of the cup very rapidly, while the air inside can get out only slowly and hence a pressure is created in the porous cup which will force the acid-level down in the beaker and up in the tubes immersed in it, thus completing the circuit and lighting the lamp.

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On stopping the flow of gas, the light gas comes out from the porous cup faster than air goes in, and the reverse action takes place, putting out the light.

The stream of hydrogen from a pressure tank will operate this device from a distance of more than two meters.

This device may also be shown to be capable of operating in the reverse direction.

Some additional electrolyte is added by means of a pipette until the lamp just remains lighted. This can be easily accomplished by sucking up some of the electrolyte in a capillary pipette made of ordinary tubing, and introducing it through the glass tube in which is the lead wire.

If now a heavy gas like carbon dioxide is made to surround the porous cup, the air will come out faster than the heavy gas gets in and a reduced pressure will result. This will so change the level of the electrolyte that the light will be extinguished.

Chloroform poured onto the stopper of the porous cup in such quantity that it does not flow over the edge, but covers the whole of the top, will soon evaporate and surround the cup with its heavy vapor. The light will be extinguished but vigorous fanning will dispel the vapor again.

Chlorine and sulfur dioxide work well as heavy gases for this experiment, but their disagreeable odors make them undesirable.

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EXPERIMENT NO. 50

COPPER PLATING OF PHOSPHORUS

A stick of phosphorus 8 cm. long by 2 cm. in diameter is scraped clean and put into a wide mouthed glass stoppered bottle in which is a concentrated solution of copper sulfate.

After the lapse of a short time the copper will have plated out on the stick of phosphorus and if time enough is allowed, the solution will have become colorless. This can be used as a good method to protect the phosphorus from the action of air when it is being cut, and it also serves to prevent the hands from coming in contact with the phosphorus, thus avoiding the use of tongs.

This is a very fine way to illustrate to students the difference between ions and atoms. Ions of copper are blue but atoms are salmon pink. This color of pure copper can sometimes best be seen by peeling off some of the adherent copper and looking at its under side.

EXPERIMENT NO. 51

TIME REACTION OF ARSENIOUS ACID

The time reaction of iodic acid is very well known, but the time reaction of the precipitation of arsenious acid with hypo, not so well known, was worked out by Professor Forbes of Harvard.

To show this, take 5 grams of arsenious oxide As_2O_3, 25 cc. of concentrated HCl and 400 cc. of water. Boil this mixture for five minutes, cool, and filter the solution.

Add this, in equal volume, to a solution made by diluting a saturated sodium thiosulfate (hypo) solution with its own volume of water to get a reaction which will start to precipitate in 20 seconds.

The exact procedure to show this to a class is carried out in this way. The solution of arsenious acid (100 cc.) is contained in a 100 cc. measuring cylinder, and the same volume of hypo solution is contained in another 100 cc. measuring cylinder. At a given instant, noted on a time piece, the solutions are poured simultaneously into a 200 cc. measuring cylinder which is then inverted several times to mix the solutions thoroughly. It will be found with these concentrations, that a very slight change in the concentration will have a very marked effect on the time. So it is important that the jars be dry at the start of the experiment.

The precipitate which sticks to the side of the jar is easily cleaned off with ammonium hydroxide.

EXPERIMENT NO. 52

INFLAMMABILITY OF CARBON BISULFIDE

That carbon bisulfide can be very easily ignited, even without the presence of a flame, can be shown in this manner.

Five cc. of the liquid are poured into a watch glass which is set on an asbestos pad. A thermometer reading to at least 250° is warmed very gradually in the Bunsen flame, the heating being greatest at a point just above the bulb. When this has been thoroughly heated, the bulb is gradually heated until both bulb and about 2 cm. of the stem are heated to around 250° C.

If now, this heated end is moved about over the surface of the carbon bisulfide, the vapors will take fire.

Put the flame out by covering with a crystallizing dish or beaker.

The vapors may be relighted several times before the thermometer becomes too cool.

A glass rod is just as effective when properly heated but the thermometer gives the temperature which can be read to the students.

EXPERIMENT NO. 53

LOW VAPOR PRESSURE OF SULFURIC ACID

The fact that ordinary concentrated sulfuric acid has less vapor pressure than the water vapor in ordinary air, is very convincingly shown by putting 50 cc. of concentrated commercial acid into a 100 cc. cylindrical graduate capable of holding a considerable excess over this amount. This should be put in some conspicuous place where students may see it.

After a time it will be noted that the volume of the acid is increased and it will continue to increase until the bulk of the diluted acid is well over the 100 cc. mark. It has been known to go as high as 120 cc.

If a graduate is chosen the 100 cc. mark of which is 5–6 cm. below the top, there is little danger that the liquid will overflow. It is obvious that the increase in bulk will cease when the vapor pressure of the solution is equal to the vapor pressure of water in the atmosphere.

To insure having the sulfuric acid in a moist atmosphere it is best to place a wide beaker with water in it near the graduate and cover both with a bell jar.

This experiment shows students why the acid bottle in a fire extinguisher is never more than half filled with the concentrated acid.

EXPERIMENT NO. 54

REDUCTION OF NITRIC ACID TO AMMONIA

To show the remarkable reducing power of nascent hydrogen, take 50 grams of zinc dust in a rather tall beaker, and add 10 cc. of a solution of nitric acid (1 part concentrated nitric to 10 parts water). Stir until a thick paste has been formed. In a moment or two the reaction becomes very vigorous and clouds of ammonia pour out, which fact can be demonstrated by suspending just in the mouth of the beaker, a moistened strip of red litmus paper or by holding in the fumes a glass stopper moistened with concentrated hydrochloric acid.

$$HNO_3 + 8\,H \rightarrow NH_3 + 3\,H_2O$$

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

It would seem that there must be an intermediate product, ammonium nitrate, formed in this reaction, and this seems to be substantiated by an experiment which this supposition led the author to try. A saturated cold solution of ammonium nitrate, (250 cc. lot) contained in a wide mouthed 500 cc. beaker, placed in a shallow tray has 20 grams of zinc dust added and well stirred in. A violent reaction begins almost at once, so violent that it pays to stand a safe distance away.

Clouds of ammonia are likewise evolved in this experiment.

If you would like to show your class how easily a fire could be started spread a smooth circular layer of well dried powdered ammonium nitrate about 8 cm. in diameter and 5 mm. thick on a fire proof surface (asbestos). On this put a similar layer of zinc dust. In the center make a depression in the zinc dust all the way through to the nitrate layer so that you see nitrate crystals. One drop of water in the depression will make this pile blaze with furious vigor.

This experiment shows how easily a laboratory could be set on fire if zinc dust and ammonium nitrate were stored together and both containers became broken. A leaky roof and even a heavy fog might set the building afire.

EXPERIMENT NO. 55

NITRIC ACID FROM THE AIR

A lecture table demonstration of the formation of nitric acid by the passage of sparks through moist air, is easily carried out.

An induction coil capable of giving one-inch spark is needed. A 500 cc. round bottom flask is clamped inverted to a ring-stand. Fitted to this flask is a 2-hole rubber stopper through the holes of which glass tubes are thrust, these tubes being of such length that they reach to the middle of the spherical part of the flask. The lower ends of these tubes should be bent slightly, so that the distance between the extremities shall be somewhat greater than the distance between the two holes in the stopper.

Number 18 copper wires are pushed through the tube and bent over the edge of the tube in such a way that they cannot slip out, and so that their ends are about 3 mm. apart. The outer ends of the wire are connected to the terminals of the induction coils. If now the inside of the flask is moistened thoroughly with water, and the terminals are placed in position, the passage of sparks across the gap made by the wires will cause the oxygen and nitrogen of the air to combine, forming brown fumes in 1 or 2 minutes.

These will be dissolved by the water and if a piece of blue litmus paper has been previously made to stick to the inner walls of the flask, it will be seen to turn red, showing the formation of an acid.

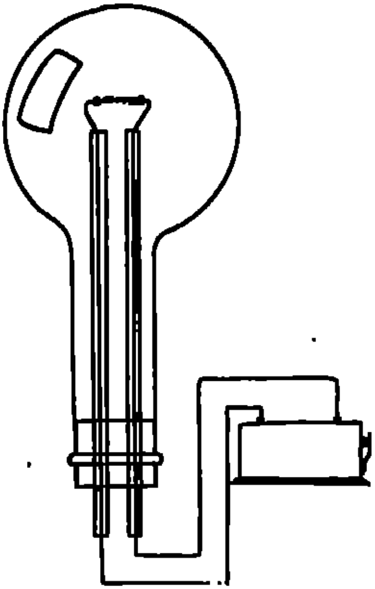


FIGURE :8

After running the device for 10 minutes, take the flask off the ring-stand and put in 10 cc. of distilled water. Rinse the walls of the flask thoroughly with this and add a very little neutral litmus solution.

That the acid is actually nitric acid can be shown by the usual test for a nitrate.

The reactions involved in the experiment may be indicated thus:

$$N_2 + O_2 \rightarrow 2\,NO$$
$$2\,NO + O_2 \rightarrow 2\,NO_2$$
$$H_2O + 2\,NO_2 \rightarrow HNO_3 + HNO_2$$

EXPERIMENT NO. 56

BURNING OF ACETYLENE IN CHLORINE

The orthodox method of showing the union of chlorine with the hydrogen of a hydrocarbon is to warm some turpentine (a hydrocarbon), dip a piece of paper into this, and then into a jar of chlorine. This works successfully, but gives such penetrating and pungent odors that it is too uncomfortable as a lecture table demonstration. The same thing may be very pleasantly shown with a jet of acetylene from a Prest-o-lite tank.

$$C_2H_2 + Cl_2 = 2\,HCl + 2\,C$$

This is done by using a jet made by bending the smaller end of a blow pipe into a semi circle whose diameter is about 1½ cm. This jet is connected to the tank by means of a rubber tube and the flow of acetylene through it is regulated until, when lighted, it will make about a 2 cm. flame.

The flame is now blown out and the jet is immersed into a jar of chlorine whereupon it will be seen to take fire spontaneously with the evolution of a very copious black smoke.

The hydrochloric acid which is produced at the same time can be tested for by bringing to the mouth of the hydrometer jar, while the gas is still burning within it, a piece of filter paper which has been dipped in strong ammonia water. White clouds of ammonium chloride will be produced.

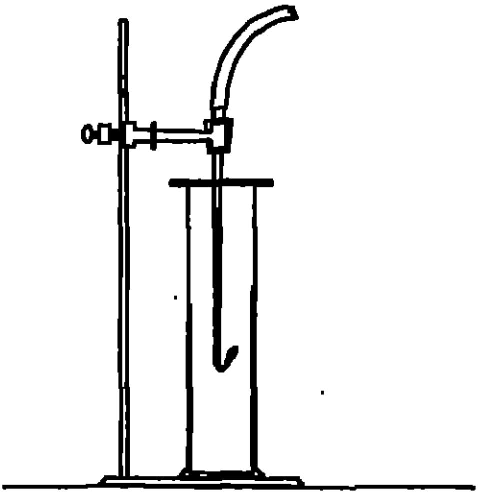


Figure 19

It is best to perform this experiment in the hood, since with carbon burning imperfectly and with an excess of chlorine present, there is some chance for the formation of phosgene, which is poisonous.

$$C_2H_2 + Cl_2 = 2\ HCl + 2\ C$$
$$CO + Cl_2 = COCl_2 \text{ (phosgene)}$$

EXPERIMENT NO. 57

SUPER-COOLING OF A LIQUID

The super-cooling of a liquid is beautifully shown by taking a 2½-liter bottle of glacial acetic acid whose freezing point is 16°C. and cooling it for about 1 hour in ice water. The experiment is generally found to be successful if the bottle is immersed in a pail of ice water at the beginning of the lecture period and allowed to cool until near the end of the lecture.

Sometimes simple shaking will start the crystallization. The rubbing of the glass stopper in its seat, or the "tickling" with a glass rod will sometimes give nuclei on which the crystals will form. To insure crystallization, have a little of the acid frozen solid in a test tube by immersing in ice and salt. If other means fail, scrape out a crystal by means of a glass rod and "seed" the super-cooled liquid with this.

Cooling the acetic acid out of doors is generally practiced but it is too uncertain, the conditions being so variable.

The method here stated practically always gives a good result.

EXPERIMENT NO. 58

A SUPERSATURATED SOLUTION

The best substance to show supersaturation seems to be sodium acetate.

Put 576 grams of C.P. crystallized sodium acetate in a bottle or flask capable of holding slightly more than a liter. Select for this experiment a bottle whose inside surface is smooth and use a cork rather than a glass stopper. Add 600 cc. of distilled water and place the bottle in cold water in a pail, bringing the water therein up to boiling and keep it thus until all of the acetate is dissolved. Then boil for ten minutes more.

This ratio of acetate to water has been found to work very well.

The stopper (cork) should be boiled in the water while the bottle is being heated to dissolve any crystals that may be on it from previous use.

When all the acetate is in solution place the bottle in a quiet place, near or at the location at which it is to be shown, with the stopper placed lightly on the mouth. Contraction on cooling will cause a vacuum which will hold the cork too firmly if it is put in tight at first.

About two hours should be allowed for cooling. This must not be hastened by any process.

When the temperature has reached room conditions twist out the stopper gently. Sometimes the inrush of air will start the crystallization. The most spectacular way to accomplish this, however, is to dip into the middle of the solution a glass rod 25 cm. in length leaving on its end a large knob. Crystallization may now start, but if it does not, remove the rod and rub the end with the finger until crytals form on it. Return it to the middle of the solution and watch the ball of crystals form and grow until the bottle is so solidly filled that it may be lifted by the glass rod. This solution may be used repeatedly.

EXPERIMENT NO. 59

SOLUBILITY OF IODINE

A few flakes of iodine are shaken with 200 cc. of water and the class shown that very little has gone into solution. A minute quantity of potassium iodide is now dropped in, whereupon the brown color of the solution indicates that iodine has dissolved.

If now this is poured into a separatory funnel and a layer of chloroform (about 100 cc. in bulk) is also poured in and the mixture shaken, it will be seen that the iodine has gone from the water into the chloroform as will be made evident by the purple color of the chloroform layer.

The watery lower layer is now completely withdrawn and a solution of sodium hydroxide (200 cc. of 10 per cent solution) poured in with the chloroform layer. On shaking these two together the purple color will disappear since sodium hydroxide forms a compound with the iodine and only uncombined iodine gives chloroform a purple color.

After all color has disappeared add 100 cc. of 1-4 dilute hydrochloric acid. This will set the iodine free again in quantity enough to produce on shaking, a reappearance of the purple color of the chloroform layer. The watery layer is now completely withdrawn and a large excess of potassium iodide solution is added (200 cc. of 10 per cent solution) to the chloroform layer.

Potassium iodide is supposed to act with free iodine to form the unstable compound KI_3

$$KI + I_2 \rightleftarrows KI_3$$

On shaking this mixture now, the color of the chloroform layer will be largely removed, showing that the iodine has gone from the uncombined state to the combined state. In the watery layer the KI_3 breaks up enough to color the solution brown but the large excess of KI sends the equilibrium to the right as represented above and most of the iodine is combined.

EXPERIMENT NO. 60

SACRIFICIAL METALS

If two different metals are in contact in the presence of dilute acid, the one which is more positive in the electromotive series is the one acted upon by the acid. Hence one metal acts to protect another. Practically "galvanized" iron is better than "tinned" iron, since once the coating is broken in acid, the zinc of the galvanizing is dissolved rather than the iron, while in tinned iron it is the iron which sacrifices itself and saves the tin. This is splendidly shown on the lecture table to small classes or given as an individual experiment in the laboratory by taking four steel pens and inserting in the prong of No. 1 a piece of zinc, in No. 2 a piece of tin, in No. 3 a piece of magnesium, and in No. 4 a piece of copper. These pieces should be very thin and clean. Four beakers are provided, in each of which there are 100 cc. of water to which have been added two drops of dilute sulfuric acid and two drops of potassium ferricyanate solution. One pen with its accompanying metal is dropped into each of the beakers. On allowing them to stand for a few moments it will be noticed that the solutions into which pens No. 2 and No. 4 have been dropped have turned deep blue, due to the formation of Turnbull's blue, showing that the iron has passed into solution; but the solutions in which pens No. 1 and No. 3 were put show no blue coloration whatever since it is the metal other than the iron which dissolves in these cases.

EXPERIMENT NO. 61

THE CORROSION OF IRON

The fact that the iron in a piece of "tin" (which is tin coated iron) rusts faster than the iron in a piece of "galvanized" iron can be beautifully demonstrated to a class in the following manner.

Secure a stick of zinc and a stick of tin both of the same size. Near one end of each wrap about ten turns of fine iron wire. Put a rubber band cut from gas tubing over the loose ends of the wire to hold them in place.

Fill two hydrometer jars (or 250 cc. graduates) with water and to each add two drops of concentrated sulfuric acid. Also add drops of potassium ferricyanide solution until the solution on mixing is slightly yellow in color.

To insure uniformity in the two jars it is best to mix both solutions in a larger vessel and pour half into each jar.

Stand the sticks in the jars, the wired ends upright, and soon the ferrous sulfate formed by the iron in contact with tin will produce Turnbull's blue. But the iron in contact with the zinc will not go into solution and hence no blue color will be seen.

Consultation of the table of the Electromotive Series will show that iron stands between zinc and tin, zinc being the highest in the series. Thus if iron should go into solution in the case where zinc is present it would at once be precipitated out again. But tin has no such power, being lower in the series.

EXPERIMENT NO. 62

THE HYDROLYSIS OF AMMONIUM SULFATE

A solution of ammonium sulfate on boiling becomes acid, due to the hydrolysis of the ammonium sulfate to form ammonium hydroxide and sulfuric acid. The ammonium hydroxide being easily decomposed into volatile ammonia gas and water, leaves the solution and the remainder contains the excess of sulfuric acid. This can be very nicely shown by taking about 5 grams of chemically pure ammonium sulfate and 200 cc. of water and boiling this in a flask which is provided with a one-hole rubber stopper carrying a doubly bent delivery tube. This is so mounted that it may be heated by a Bunsen burner, and a flask containing 200 cc. of water to which has been added a few drops of phenolphthalein solution is placed so that the delivery tube is about .5 cm. above the water. On boiling the ammonium sulfate solution the phenolphthalein will turn pink.

The experiment can be made even more striking by putting a few drops of phenolphthalein into the ammonium sulfate solution and adding enough sodium carbonate solution to produce a decided pink color. On boiling, this pink color disappears and soon after the water in the receiving flask becomes pink. On cooling the ammonium sulfate solution the pink color reappears to some extent, probably due to the fact that heating favors the union of the NH_4 ions with the OH ions present, forming undissociated ammonium hydroxide.

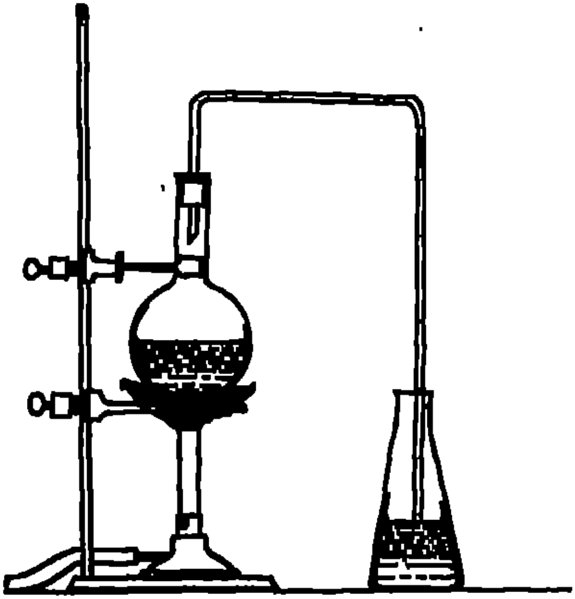


FIGURE 20

That this is the explanation appears to be true from the following experiment.

A 250 cc. flask is filled half full of distilled water and about 2 drops of ammonium hydroxide are added. Drops of phenolphthalein are added until a decided pink color is obtained. On heating this solution now the pink color will all disappear, but it will reappear when the solution is cooled again.

This experiment illustrates the method by which the weedless lawn was produced at Rhode Island State College. The plants take up the ammonia and the acid left in the soil is unfavorable to weed growth but does not inhibit the growth of grass. (Rhode Island Bent.)

EXPERIMENT NO. 63

PROTECTIVE COLLOIDS

Students should be shown that certain substances prevent the successful precipitation of many substances. A good example is the effect of gum arabic on silver chloride precipitate.

Make solutions as follows:

a. One gram silver nitrate in 200 cc. distilled water.

b. Five cc. concentrated C.P. hydrochloric acid in 40 cc. distilled water.

c. Five grams gum arabic in 100 cc. distilled water.

Take two 500 cc. hydrometer jars holding 400 cc. distilled water each. To one add 10 cc. of solution (c) and mix well by inversion. Now to each jar add 10 cc. of solution (a) and mix, and 10 cc. of solution (b) and mix.

The gum arabic so separates the reactants that only small quantities can get into reacting distance at a time and the resulting precipitate is very finely divided and remains in suspension while the one not protected is coarser and will, on standing, settle out.

The rapid reduction of the protected one by sunlight should be shown. If both jars are put in direct sunlight the fineness of subdivision of the protected precipitate renders the action very rapid and in a few moments it will become blue in color while the other is only slightly changed. If the two jars are left for a day the unprotected precipitate will have settled out leaving a clear solution and the other will be deep blue. This protected precipitate is made use of in the photographic film the speed of which depends on the size of the granules of silver halide.

EXPERIMENT NO. 64

EQUIVALENT OF ZINC (or magnesium)

Many pieces of apparatus have been devised for doing this experiment before a class, but in many of them there is the possibility of having small bits of the metal escape without reacting.

The device here described seems to obviate all of this trouble and is extremely simple.

A hydrometer jar 30 x 5 cm. is filled with water at room temperature. A 50 cc. gas measuring tube whose length is about 65 cm. and whose external diameter is about 13 mm. is filled to the mark with concentrated commercial hydrochloric acid and filled up the rest of the way to overflowing with water at room temperature.

A cork which will fit the gas measuring tube so that it can be pushed in its full length and which has a small V shaped notch cut lengthwise along its side, is provided. A piece of zinc wire whose weight is about (and not over) 0.1 gram, but whose exact weight is known is also provided. Stick this wire into the cork as short a distance as will be sufficient to hold it and place the cork nearly or quite its full length into the open end of the gas measuring tube. Holding the thumb over the notch in the cork, invert the tube into the hydrometer jar, placing it in an oblique position so that if the gas measuring tube slants to the left, the notch in the cork will be on the right. This will insure that particles, which may be detached from the zinc wire and which rise because of their attached hydrogen bubbles, will, when they fall, be still retained because they fall on the side of the cork away from the notch. After all action has ceased get the levels of liquid in the two vessels the same and read the volume. If it is impossible to get the level in the inner tube the same as the level in the hydrometer jar, measure this difference in levels in mm. and divide by 13.6, adding this to the barometer pressure if the level in the inner tube is lower, and subtracting it if it is

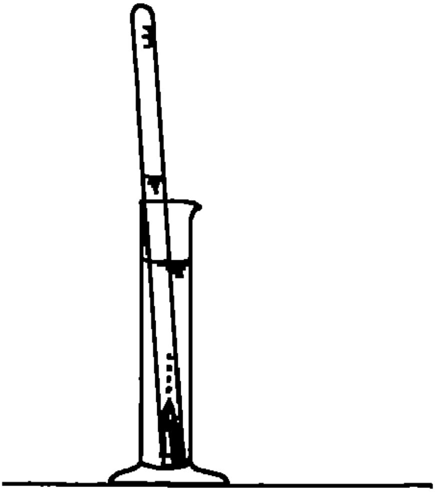


FIGURE 21

higher than the level in the hydrometer jar. It is best to find by trial what weight of zinc is needed to produce hydrogen enough so that the level in the inner tube will be below that in the hydrometer jar, in which case the levels can be adjusted so as to coincide. The correction of this gas volume to standard can be quickly made using the formula

$$\text{Vntp} = \text{V}' \frac{\left(\text{P}' - \text{a} \pm \dfrac{\text{difference in levels}}{13.6}\right) 273}{760(273 + \text{t})}$$

where V′ is the observed volume of gas, P′ equals the barometer pressure at the time of the experiment, a equals aqueous tension at the temperature t, and t equals temperature of the room at the time of the experiment. This factor by which V′ is to be multiplied may well be worked out by the students while the experiment is in progress. The volume of hydrogen is quickly converted into the weight of hydrogen by multiplying the volume in *liters* by .089. The equivalent of zinc being the weight of zinc needed to liberate 1 gram of hydrogen, is easily found from the equation

$$\frac{\text{X}}{\text{Wt. of zinc}} = \frac{1}{\text{Wt. of hydrogen obtained}}$$

where x = amount of zinc required to liberate 1 gram of hydrogen. This whole experiment can easily be carried out in 15 minutes and much can be learned by the students while the experiment is in progress.

EXPERIMENT NO. 65

CONDUCTIVITY OF SOLUTIONS

The usual method of showing conductivity of solutions with platinum electrodes in a bottle or beaker involves so much cumbersome washing and drying of the apparatus that the following device offers great relief. The device is always ready, does not have to be taken apart and can be washed or dried instantaneously.

The illustrations are nearly self explanatory.

A centimeter length of platinum wire of 1 mm. diameter is welded to a copper wire of about the same size. This is easily done by placing the wires on an asbestos pad, lapping a millimeter or two, and directing a very small blast lamp flame down on the lap from above until fusion takes place. The copper wire should be about 20 cm. long.

The two wires with platinum ends are clamped parallel and close together so that a millimeter space separates the platinum tips. Lead glass is now wrapped around these near the end, by heating a rod of the glass in an oxygen-gas flame until it is soft enough to work easily. By adding enough of the lead glass a globule will finally form, enclosing the platinum wires for about half their length.

The copper wires are then slipped through a length of soda glass tubing and the lead glass head fused to its edge. The annealing of this joint must be very carefully done and is best accomplished by wrapping the hot joint in cotton.

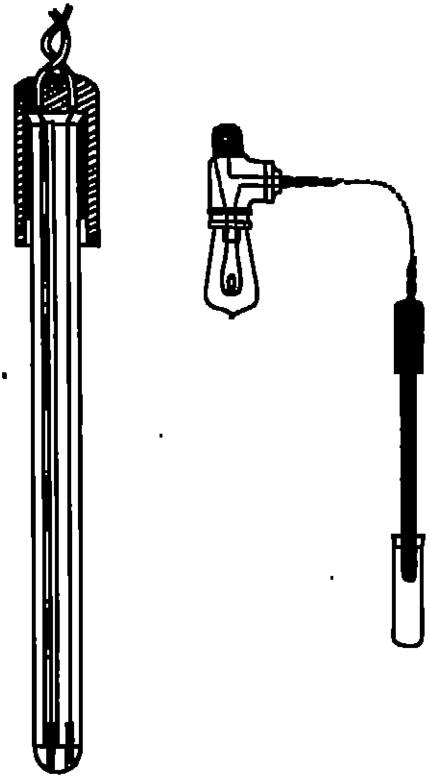


FIGURE 23

The platinum wires are smoothed off flush with the surface of the glass to give ease in drying, which can be accomplished with a cloth or with filter paper.

For convenience in handling the tube is set into the wooden cover of a thermometer case and cemented in with sealing wax. The rest of the case is used to protect the device when not in use.

About 1½ meters of lamp cord connect this device with the Hubbell series side tap receptacle with a 10-watt lamp.

The substances to be tested (qualitatively only) are put into small test tubes in a rack or into small Erlenmeyer flasks, which are set in a row. The electrode is dipped successively into these substances with washing between each two. The washing may be done with tap water if it is not a conductor, as shown by this apparatus, at the time the experiment is done. Otherwise, distilled water may be squirted onto it from a wash bottle.

Suggested list of substances to test before the class is here given:

	No glow	*Dull glow*	*Bright*
1. Dry salt	X		
2. Distilled water	X		
3. Tap water		X (sometimes)	
4. Salt solution			X
5. Ammonium hydroxide (dil)		X	
6. Ammonium hydroxide (conc)	X		
7. Sodium hydroxide			X
8. Glacial acetic acid	X		
9. Dilute glacial acetic acid		X	
10. Hydrochloric acid			X
11. Sulphuric acid (dil)			X
12. Sulphuric acid (conc)			X
13. Nitric acid (dil)			X
14. Glycerine	X		
15. Alcohol	X		
16. Sugar	X		
17. Sugar solution	X		
18. Lime water			X

The fact that the apparatus does not have to be taken apart for washing and drying makes it possible to show this whole list in about 15 minutes.

It is astonishing to the students to see that 2 cc. of concentrated hydrochloric acid is enough to render a whole 3-liter battery jar of water a conductor.

EXPERIMENT NO. 66

RATE OF SETTLING OF SUSPENSIONS

The influence of adsorbed charges in keeping fine suspensions from settling out quickly can be easily shown.

Two footed test tubes of about 100 cc. capacity are each nearly filled with distilled water. To each is added 0.1 gram finely powdered kaolin (china clay). To one is added 5 drops concentrated HCl and to the other 5 drops concentrated NaOH solution.

The clay appears to have a preference for (OH) ions and adsorbs them onto its surface. Thus the particles, being charged alike, tend to repel one another and the rate of settling is very slow. The acid suspension will settle out perfectly clear in a day but the basic one will take weeks and may never settle out if the clay is very fine.

The tubes should be stoppered tightly with corks which have been soaked in melted paraffine and are of such size that they will slip below the lips of the tubes. The corks are then paraffined into permanent position. Thus prepared the tubes may be shown from year to year.

They should be first exhibited to the class after they have been standing long enough to show the difference.

EXPERIMENT NO. 67

QUARTZ GLASS

A striking way to show the low coefficient of expansion of this glass is to heat a quartz dish such as a crucible or an evaporating dish to a dull red heat and drop it into cold water. Or the dish may be placed in a ring with a burner under it and water dropped into the dish from a dropping funnel clamped above it. For this the dish must not be heated to such an extent that the "spheroidal state" of water will be reached.

If any students have never noticed water on a very hot surface, however, it will be well to show it after the class is over. Heat the glass red hot with no water dropping, and then let drops enter at intervals of about five seconds. They will coalesce and roll about without boiling until the globule is two centimeters or more in diameter.

EXPERIMENT NO. 68

SEPARATION OF A NON-WETTED FROM A WETTED POWDER

Make a mixture of 5 volumes powdered glass and 1 volume of lamp black. Put this into a small sieve and hold the latter about 5 cm. above the surface of

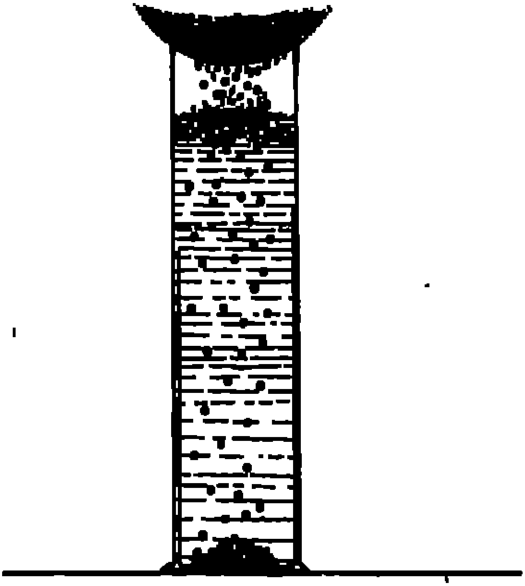


FIGURE 22

water in a cylindrical precipitating jar. Tap the sieve gently, whereupon it will be seen that the glass goes to the bottom of the jar but the lamp black stays on the surface of the water.

Do not continue the tapping long enough to get a thick layer of lamp black, for then the mixture will accumulate above it and finally tear through the surface of the water carrying a mass of lamp black and glass to the bottom.

By putting on a fairly thick layer, however, and then tapping the precipitating jar instead of the sieve, much of the glass can be made to go through without carrying any lamp black.

This serves to show the principle by which some ores are separated from the rock in which they occur.

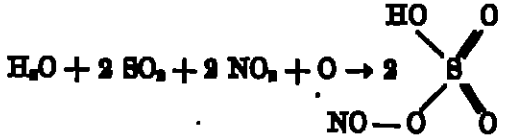
EXPERIMENT NO. 69

THE CHAMBER PROCESS

Reactions. A very simple demonstration of the reactions involved in the chamber process can be shown if a tank of sulfur dioxide is available, as it should be in every elementary laboratory. A hydrometer jar of about 50 cm. height has poured into it 5 cc. of fuming nitric acid. The jar is then tipped into a horizontal position and rotated so that the acid runs in a spiral toward the top. A jet from the sulphur dioxide tank is led by a glass tube to the bottom of the jar, now upright, whereupon the "chamber crystals" coat out on the sides.

The reactions involved so far may be explained thus:

$$2\,HNO_3 + SO_2 \rightarrow H_2SO_4 + 2\,NO_2$$

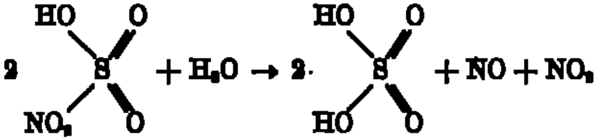


$$H_2O + 2\,SO_2 + 2\,NO_2 + O \rightarrow 2\,(HO)(NO{-}O)SO_2$$

nitrosyl sulfuric acid
(chamber crystal)

The water is present in the acid and the oxygen comes from the air. When a good coating of these crystals has been formed the stream of sulfur dioxide is cut off and a stream of steam run in from a boiler, using the same glass tube for a delivery tube.

The crystals will soon dissolve and the oxides of nitrogen will be regenerated as the reappearance of brown fumes will indicate.



$$2NO + \underset{\text{air}}{O_2} \rightarrow 2NO_2 \text{ brown}$$

Run steam until these fumes are all cleared out and then add water gradually to fill the hydrometer jar one-third. Mix the contents of the jar, pour one-half into another container. To one-half add barium chloride solution followed by C.P. hydrochloric acid to test for the sulfate. To the other half add blue litmus solution to show that an acid was formed.

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